POINT TO POINT

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Volume Six Number One October 1961

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Points of view

TO THE EXTENT that there has been any recurring theme in *Point to Point Telecommunications* since its inception five years ago, it has been that the provision of facilities for telephone services on an international basis, and sometimes on a national basis as well, has consistently, for many years, lagged more or less substantially behind potential demand. The reasons for this are many and sometimes obvious, the most important being shortage of capital for the necessary expansion. We feel, however, that the lack of capital is in part due to the poor case for adequate expansion which is made out by the planners, perhaps due to the absence of the necessary statistics. This is illustrated at least in part by the development of the telephone network in the United States, an area of such size that many of the trunk circuits are comparable to international systems in other areas, such as the Continent of Europe. In the United States there has been little, if any, restriction on capital investment, with the result that there exists a telephone network unequalled in the rest of the world (with the possible exception of Sweden).

Despite five years' experience on the transatlantic telephone cable, TAT-1, where demand has so consistently exceeded the planners' estimates that, first 3 kc/s channelling and subsequently the TASI system have had to be pressed into service, we suspect that the old conservatism is still at work in estimating the future traffic requirements on intercontinental networks, and therefore the provision of facilities will from the outset be conservative—we might say pessimistic rather than optimistic.

We believe that the development of inter-continental telephone traffic has been frustrated to a greater extent than is generally recognized by limitations of capacity and quality of service. An intensive analysis of

the available information, not only on telephone traffic but in other forms of communication, suggests that the sort of growth figures which the statisticians are talking of in their long-range forecasts up to the 1980s are pessimistic by even as much as an order of magnitude.

It is very important that the estimates made within the next few years should be realistic, since we are close to the point of implementation of two complementary techniques, repeatered undersea coaxial cable and fixed services communication via satellites. As is stated elsewhere in this issue, we believe there is room for both of these techniques.

One of the chief difficulties in assessing future demands for telephone communications is the effect of waiting time upon traffic. We would hazard a guess that where a connection time of less than an hour is involved this will be tolerated, albeit with impatience, but where it exceeds an hour then a substantial loss of traffic will be incurred by diversion to competing means of information transmission such as telex or merely by air mail. Many air mail services are now such that the limiting factor is the internal mail distribution within the country concerned and therefore between territories for which telecommunication service is poor and air mail service is good, one could anticipate that a large untapped telephone traffic demand exists—a demand which could lead to increase in traffic many times greater than could be anticipated on the basis merely of extrapolation of existing traffic statistics.

It would appear that in many respects the world trunk network is at a point of critical development. A spirit of reasoned optimism at this point similar to that shown by our ancestors in developing the railway network in the nineteenth century, could lead to a degree of expansion in the next twenty years many times over that which it would appear is being used as a basis of forecasting and planning for future development.

A.J.W.

Predicted Future Expansion of Intercontinental Telephone Traffic*

M. TELFORD, B.Sc(Eng), A.M.I.E.E, and G. A. ISTED, A.M.I.E.E

The growth of intercontinental telephone traffic, and other forms of communication, is analysed in order to try and predict the future pattern of this type of telephone traffic that can be expected, particularly over the next twenty years. The possibility of establishing satellite communication networks, in addition to the existing repeatered submarine coaxial cable systems, makes the correct estimation of future traffic demand of vital importance at the present time.

1 THE EARLY DEVELOPMENT OF RADIO COMMUNICATION

WHEN ONE CONSIDERS the development of radio over the years, one may come to the conclusion that it has been somewhat haphazard and that some of the trends, considered in retrospect, have been somewhat illogical. It would not be fair to accept this as criticism of the pioneers who, under the circumstances, achieved most remarkable results. We should, however, endeavour to profit from the many missed chances, and wrong roads taken; a theme so well recorded by E. H. Armstrong.[1]

A cynic might say, perhaps with justification, that the basic difference between the radio communication engineer of the early 1900s and his counterpart of today is that the early pioneer was conscious that he knew little whereas we think we know so much. We do indeed know a great deal, but therein may lie great danger. Rating our knowledge too high, we may commit even greater mistakes than our predecessors in taking major decisions based on 'facts' which, in reality, are sometimes no more than opinions. We may thus inadvertently take the wrong road again. It cannot be overstressed that before we start our journey we must

* We thank the British Institution of Radio Engineers for permission to publish this article which is based on a paper read before the 1961 Convention on Radio Techniques and Space Research. Due to limitations of space, certain parts of the paper have been condensed but this does not represent any retraction from the views already expressed.

study the past and present, in all its reality, and use the knowledge gained to attempt to see into the future.

Let us briefly review some of the accidents or technical expediences that confused the logical development of radio as we see it today.

There seems little doubt that the early investigations by Marconi and others into means by which electro-magnetic waves could be harnessed for communication purposes, were carried out at frequencies between 500 and 1 500 Mc/s. These workers soon found that by connecting bigger and bigger radiators to the Hertz oscillator they could communicate over greater and greater distances. In this way it seems certain that they were unwittingly decreasing the natural resonant frequency of the equipment, thereby allowing better use to be made of ground-wave propagation.

In 1882 Balfour Stewart[2] postulated the presence of conducting ionized regions above the surface of the earth. In view of this, it was in 1896 that perhaps the biggest missed chance in the history of radio occurred, that of using ionospheric reflection of radio waves as a means of long-distance communication. This was no doubt greatly influenced by a glittering prize of £20 000 offered by the British Admiralty for a means by which a ship could signal her presence to a friendly port without at the same time revealing herself to the enemy.

The prize was won by Marconi, who devised an aerial/earth system whereby one side of the Hertzian oscillator was connected to the hull of the ship, while the other side was connected to an insulated long vertical wire. The dimensions of the typical ship of those days makes it almost certain that the resulting resonant frequency of such an aerial/earth system would be between 1 and 2 Mc/s,[3] at which frequencies there is almost complete ionospheric absorption and only limited range is possible. As a result the potentialities of reflection of radio waves from the ionosphere were overlooked for nearly 30 years.

The successful transatlantic experiment in 1901 by Marconi, which must have been conducted on a frequency of about 150 kc/s, established the ' lower the frequency the greater the range ' concept. As a result of further observations, Marconi came to the conclusion that lower frequencies gave an improvement in the so-called ' daylight ' effect whereby the propagation of radio waves sustained a serious loss in amplitude

during the daylight hours. Other experimenters in several countries confirmed Marconi's conclusion and, as Armstrong says, 'transoceanic communication went down the road of longer and longer wavelengths'.

It was not until nearly a quarter of a century later that the situation was rectified, also by Marconi, by the discovery that the 'commercially useless' high frequencies gave a better means of long-distance communication.[4] One wrong road was thus avoided when the extravagant Empire Wireless Communication chain of high-power long-wave stations was rudely thrust aside in 1926 in favour of the much more economic Imperial Short-wave Beam network.

2 THE PRESENT STATE OF COMMUNICATIONS

Our knowledge of the parameters controlling the propagation of radio waves has matured since the inception of long-distance communications at high frequencies and we now have a picture of the earth endowed with an encircling atmosphere which enables radio waves to propagate effectively over very great distances. In the upper atmosphere, solar radiations maintain ionized regions capable of reflecting a radio wave back to the earth. The lower atmosphere creates a radio horizon substantially further away than the optical horizon, while turbulence and discontinuities in the constituent elements make it possible to scatter waves in the VHF band and above to distances well beyond this horizon. The benefits derived from the earth's atmosphere (considered as a transmission medium) are incalculable; its inherent irregularities and instabilities, however—many of which are attributable directly or indirectly to solar phenomena—set a limit to radio performance. The natural phenomena of terrestrial and extra-terrestrial noise, together with man-made sources of noise, lead to further restrictions.

Communication over distances of 30-60 miles (between repeaters) by means of microwaves, with a telephone channel carrying capacity up to 600 or 960, is now well established and systems of this type are used to a large extent as overland trunks between major population centres. The present trend in this context is towards higher frequencies where wider bandwidths and greater channel carrying capacity are more easily obtainable.

In the particular case of long-distance communication by high frequency waves via the ionosphere, we are able to establish upper and lower limits of operating frequency, which vary cyclically from day to night, season to season and year to year. The eleven-year cyclic variation is of very great concern to the communication engineer, because at sunspot minimum the upper limit and the available band of frequencies are both greatly reduced. A further complication, as shown by the different conclusions of Millington,[5] Hitchcock[6] and Minnis,[7] is the uncertainty of the ultimate degree of activity as each maximum and minimum approaches.

It is well known that even during the last sunspot maximum the interference inflicted on high frequency communication circuits by other users was the most frequent cause of traffic 'outages'. The reason for this can easily be seen by a quick glance through the I.T.U Radio Frequency Record, where it will be found that it is not unusual for a single operating frequency to be allocated to a dozen users. Further, it has been shown by Humby[8] and Wirsu[9] that, interference apart, communication cannot be supported on some East/West circuits for considerable daily periods during the few years around sunspot minimum. The severity of the chaotic situation at the next sunspot minimum can be left to the imagination.

A great deal could no doubt be done to alleviate the situation by rationalizing our long-distance communication techniques. The present arrangement of our international and intercontinental networks makes a spider's web look simple by comparison, and certainly leaves no doubt whatever which of the two was designed by the more competent architect.

Most communication engineers will probably agree that not only has our present radio system reached saturation, but also, being so dependent upon fickle nature for its *modus operandi*, it cannot provide the reliable high quality service which the user of today demands. At the best, the typical long-distance radio telephone circuit is narrow-band by modern standards. It is not capable of carrying more than four single-sideband telephone channels and is generally out of action for quite a substantial proportion of the time.

Despite the coming of the transoceanic telephone cable, which has transformed the situation on several major routes, there seems little doubt that we have reached the crossroads in communication and nothing short of a revolutionary change in technique will allow us to meet the demands of the future. Provided we make the right decisions now and put the future communication art upon the right road, yet another glittering prize will assuredly await us.

3 THE PATTERN OF EXPANSION OF LONG-DISTANCE COMMUNICATIONS

Before suggesting what form the revolutionary change should take, we may perhaps first consider what degree of expansion in communication is likely in the foreseeable future.

An indication of the immediate order of expansion has been obtained by requesting the overseas offices of a commercial electronics firm to state to what extent they would increase their long-distance telephone calls to their head office if, instead of high-frequency radio circuits, they could obtain a reliable alternative means of communication. The results indicated that they would increase their calls, on average, tenfold. The present number of calls in all the cases considered is certainly small, so that scaling to a general situation could be misleading. Perhaps, therefore, better guidance may be obtained in other ways. These are all of statistical form, as follows:

(1) The direct method—to plot long-distance traffic of the type we are concerned with and study its growth. We might call it intercontinental or transoceanic traffic, for want of better terms, and define it by the bearers, which are of two distinct types—HF radio and transoceanic cable. For simplicity, and because it is best documented, we will confine ourselves to telephone traffic.

(2) To compare intercontinental telephone traffic and its available facilities with other classes of telephone traffic and their facilities (e.g, internal calls in national systems).

(3) To find out what has happened statistically to other forms of communication, perhaps the most interesting cases being those which are longest established.

All three methods have their weaknesses and all are open, in common with other statistical studies, to accusations of special pleading or the drawing of improper inferences. The authors, while admitting they have a special case, will endeavour to avoid these pitfalls. Before studying the data we must look into the individual weaknesses of the methods and consider how bringing them together may give added strength.

Growth studies in this case suffer from the disadvantage that trans-oceanic telephone traffic in any form is a recent development. It really began only in the late 1920s and development was impeded by the Depression and the 1939-45 war. Insufficient statistics may therefore be available to justify derivation of an empirical equation for growth. Extrapolation then, of course, becomes very dangerous. It might also be questioned whether the growth is linear or of some other form, whether there are transients which will not be repeated and therefore obscure true interpretation. It must be considered also whether any law, of a somewhat doubtful nature, which is established will continue into the future and if so, how far.

Quantitative comparison with other classes of telecommunications traffic is also dangerous. Obviously it cannot be expected that telephone calls between London and New York subscribers, for example, will ever number more than a small fraction of those between London and Birmingham or New York and Baltimore. It might be possible to establish a reasonable scaling factor, if there was a single intercontinental route where the reliability and quantity of long-established telephone facilities were such as to bear comparison with an internal network. In the authors' opinion this is not so. While not intending to denigrate the magnificent technical achievements represented by the North Atlantic telephone cables (if it were possible to do so), it is a fact that statistics on the first of these have only been available for four years and it cannot be expected that the pattern of use has been set. What can be done quite easily, from the I.T.U General Telephone Statistics, is to compare total international traffic (of which only a fraction may be of an intercontinental nature) with national traffic. Most of the countries of the world are listed in the I.T.U documents and many interesting deductions may be drawn.

The third method is perhaps the most interesting for its own sake and the one which is not generally given sufficient weight. It may be that all of us, concerned from day to day with new and exciting developments in an expanding world of scientific and industrial interests, tend to look to the future too much and neglect the study of the past. In the field of communications there is much information to be gleaned from the history of the railways in the U.K. This shows a slow beginning, a sudden upsurge over a few decades as expansion occurred to meet the need, and a flattening in growth followed by an irregular but definite decay—kept in check in recent years by improvements in facilities.

The dangers that must be avoided, in trying to learn from such examples, include mistaking the period (and its duration) with which comparison is made, and trying to draw too close an analogy. Nevertheless, one can learn and one can compare; in a science so historically young and undeveloped as long-distance telecommunications, it may be that we cannot learn in any better way. These three methods, taken together, will give some useful indications for future planning and action.

3.1 THE GROWTH IN INTERCONTINENTAL COMMUNICATIONS

Fig.1 shows the yearly numbers of U.K originated calls carried over HF radio systems terminating outside Europe, beginning in 1927, with the later data including—in fact, dominated by—calls over the first transatlantic cable (TAT-1). The regularity of the curve which may be drawn through the points in periods where natural growth was unimpaired by influences outside engineering control is of great interest, as is the rapidity of return to this curve when the external restraints disappeared. There are two main irregularities—one obviously due to the 1939-45 war and the second from 1952 to 1957. Sunspot minimum, as defined on the figure, lasted from about mid-1951 to mid-1955 and it is hardly to be doubted that its deleterious effect on radio communications was a major cause of the 1952-57 'kink'. A further cause was certainly the sheer inadequacy of the North Atlantic radio service to cope with the traffic need at this time. The story subsequent to the installation of TAT-1 is well known—the number of North Atlantic calls from the U.K in the year ended 31st March, 1960, was three times as great as

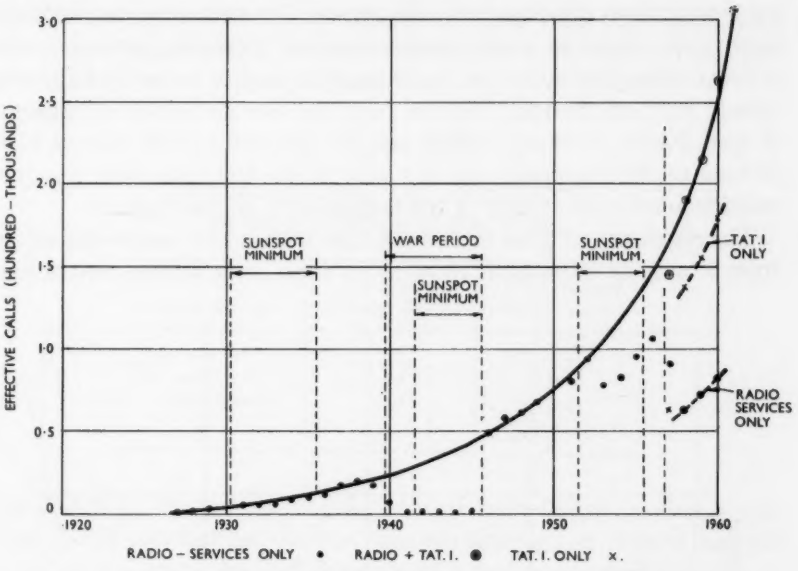


Fig.1. Intercontinental telephone traffic. U.K-originated effective extra-European calls (British P.O data). Note: Sunspot minimum periods arbitrarily defined by a value of the Zurich relative sunspot number (annual mean) of less than 50

in the year ended 31st March, 1956, while international radio calls originated in these islands had increased by about 65% only. There is little sign of slackening in North Atlantic traffic growth, and waiting times of more than an hour during the busy period are common, despite the fact that the number of circuits available on the cable has been more than doubled since its opening, by the introduction of 3 kc/s spaced channelling and the TASI (Time Assignment Speech Interpolation) system. Two further North Atlantic cables from the U.K are planned to be in operation by the end of 1964 (TAT-3 and CANTAT) and one from France to the U.S.A (TAT-2) was completed late in 1959.

Similar data for U.S.A-originated overseas telephone messages is given in Fig.2. The implied effects of the war and the 1953 sunspot minimum

are less marked, although they still appear. The very steep rise in traffic since 1945 might be partly ascribed to the increasing economic and political influence of the U.S.A, although it may be noted that approximately 60% of the total calls in 1959 was accounted for by those to Hawaii, Puerto Rico and Alaska (all U.S possessions now having cable circuits to the mainland) and to Cuba. In this last case there is a good multichannel radio system of the tropospheric scatter type.

The regularity of growth and the ease with which major departures from it may be explained, allow us to draw some simple conclusions.

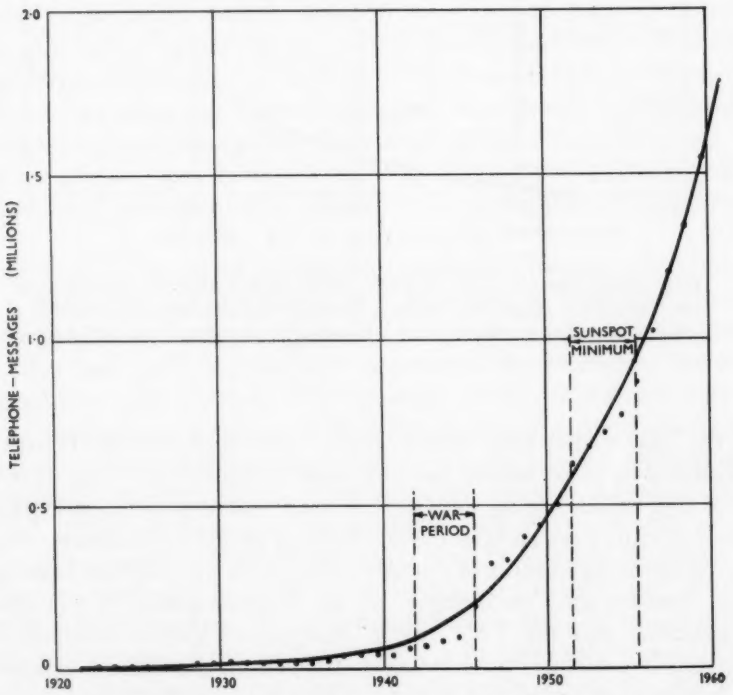


Fig.2. Intercontinental telephone traffic. U.S-originated overseas telephone messages 1920-1960 (A.T & T Co data). Note: The data from which this figure was derived gave totals of outgoing and incoming calls. These have been halved before plotting

Table I shows growth factors per decade obtained from Fig.1 and 2 data. (The 1940 figures used in these calculations were taken from the smoothed curves in order to eliminate the effects of the war.)

Table I

INTERCONTINENTAL TELEPHONE TRAFFIC GROWTH FACTORS

	U.K originated	*U.S.A originated*
1930–1940	6·0	4·4
1940–1950	3·0	7·6
1950–1960	3·7	3·5

It is doubtful if the average long-distance HF radio-telephone circuit provides 'good commercial quality' communication, as defined by the C.C.I.R (on a simple basis of the ratio of signal to atmospheric noise). This standard is substantially inferior to that laid down for overland systems using cable or microwave radio. Nevertheless, in the last thirty years U.K and U.S.A-originated calls have multiplied by about 66 and 117 times respectively. It may be that such increases would have been much greater if high quality on demand telephone facilities, linking all parts of the world, had been available. Certainly very few people make use of the intercontinental telephone system at present. U.K-originated calls via the radio services, since they began, have only totalled about 1¼ million, or roughly one per 40 of the population. It does not seem likely that more than one in 10 of these would be private calls—say approximately one call per 5 000 adults per year on average. This estimate is probably generous.

3.2 RELATIONSHIP BETWEEN INTERNAL AND EXTERNAL COMMUNICATION TRAFFIC

We now proceed to the second method, using first a quantitative comparison between different classes of telephone traffic within, or originated

from, the U.K and the U.S.A. In Table II, the numerical ratio of each of these classes to the number of intercontinental cable and radio calls is given, together with the actual figures for these calls.

Table II

COMPARISON OF DIFFERENT FORMS OF U.S.A AND U.K TELEPHONE TRAFFIC

Territory	*Total of cable and radio*	*Class of Call*			
		Local	*Trunk*	*Continental*	*Intercontinental cable and radio*
U.K[1]	263 000	14 400	1 460	10·7	1
U.S.A[2]	1 550 000	58 000	3 400		1

[1] Year ended 31st March, 1960 [2] Year 1959

Let us consider the U.K figures. It might be accepted that we, as individuals, have only one-tenth as much community of interest in those who live and work outside our local area, compared to those who live nearer. But is it reasonable to assume that our interest in those who live on the continent of Europe is reduced by a further factor of 130—or that our interest in the rest of the world diminishes yet further by a factor of 10·7? If this, in fact, is true, for a country which prides itself on a high degree of international feeling and interest, we may indeed despair! The authors do not despair—they believe it is not lack of interest but lack of facilities at reasonable cost that has brought about this sorry state of affairs. In order not to offend our transatlantic cousins, the U.S.A figures must be left to speak for themselves!

Of course, for the sake of brevity and clarity, we have over-simplified. Language and time barriers do exist, unfortunately, and their effects on global communications must be taken into account, in all planning and engineering of practical and economic systems.

In Table III, all countries, for which statistics of the type required are available, have been divided into three arbitrary categories, as follows:

(A) Countries having good telephone facilities with other countries in which they have major economic, social or political interest.

(B) Countries with moderate or poor telephone facilities with most other such countries, generally owing to physical or political barriers.

(C) Countries with, as far as is known, only HF radio-telephone facilities to all other countries included in the applicable total of outgoing international calls.

In case we may offend any national susceptibilities, we wish to give the assurance that the attempt has been made to make the division as objective as possible—but we cannot guarantee its accuracy.

For each country in each category, we quote the total number of originated effective international calls, generally for the year 1959 or the year ended 31st March, 1960, and the ratio of national to international calls for the period under review.

It will be seen that, with one exception (Lebanon), all the countries in Category A are in Europe. All have relatively high telephone development (greater than 4 per 100 population) and all but the Republic of Ireland have land frontiers with most other countries with which they have a high community of interest. The Republic of Ireland has a land frontier with Northern Ireland, and good facilities with the remainder of the United Kingdom. In Category A the ratio of national to international calls does not vary over a very great range. It is less than 100 for five out of the nine countries listed and greater than 300 for two only—France and the Federal German Republic. Perhaps a value of 300 could in general be considered a reasonable and desirable datum. The fact that the Federal German Republic had a 'ratio' of about 1 000 in 1950, compared with the present-day 450, may be considered a very significant pointer.

In Category B the range of ratio variation is much wider. Within it come many of the remaining States with relatively high internal telephone development, such as the Argentine, Austria, Denmark, U.S.A,

Table III

COMPARISON OF NATIONAL AND INTERNATIONAL CALLS

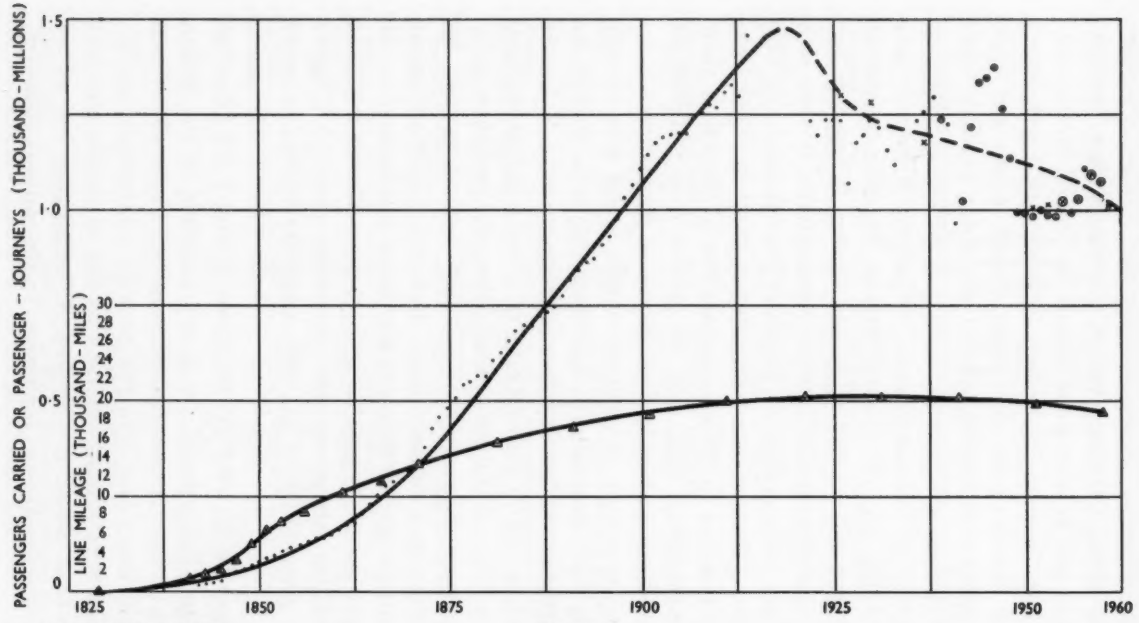
Country	*Ratio of National to Outgoing International Calls*	*Number of Outgoing International Calls*
CATEGORY A		
Monaco	11	300 326
Lebanon	20	4 880 000
Luxemburg	35	944 417
Republic of Ireland	95	1 412 000
Belgium	130	5 231 305
Switzerland	160	5 722 461
Netherlands	300	4 651 551
France	330 (est)	8 400 000
German Federal Republic	450	9 187 629
CATEGORY B		
Dominica	0·83	1 025
Sudan	27	83 922
Pakistan	34	163 667
Libya	42	16 068
Indonesia	150	29 465
Central African Republic (Congo, etc.)	160	34 007
Egypt	160	119 672
St Thome & Principe	220	69 671
Somaliland	270	3 020
Syria	280	403 650
Mauritania	310	588
Angola	390	33 503
Dahomey	440	3 778
India	450	66 303
Bermuda	490	27 375
Cameroons	590	8 565
Austria	600 (est)	1 220 016
Ivory Coast	600	11 016
Granada	670	3 079
Antigua	690	520
Denmark	770	1 701 455
Norway	770	693 952
Mali	850	16 368
Belgian Congo	900	41 851
Ethiopia	1 100	23 865
Greece	1 300	380 532
Sweden	1 300	1 845 743
Turkey	1 300	200 000 (est. 1957)
Italy	1 400	4 019 916
United Kingdom	1 400	3 073 000
Burma	1 500	3 088
Mozambique	1 500	15 377
Upper Volta	1 700	376
Niger	1 800	594
Yugoslavia	1 800	225 000
USA	3 400	26 000 000
Portugal	3 500	122 599
Spain	3 700	691 034
Republic of South Africa	4 900	218 745
Israel	6 600	33 903
German Democratic Republic	6 900	134 609
Argentine Republic	7 900 (est)	422 460
Trinidad	7 900	13 000
CATEGORY C		
Thailand	21	12 966
Macao	1 200	289
Iceland	1 500	5 919
Madagascar	1 800	5 632
New Zealand	2 100	22 458
New Caledonia	2 400	904
Nigeria	2 400	12 527
Malaya	4 000	4 266
Vietnam	4 300	4 367
Ghana	4 400	5 047
Kenya, Tanganyika, Uganda	4 900	12 370
Singapore	7 500	21 139
Japan	8 100	166 837
Australia	16 000	91 986
Polynesia	29 000	22

Necessary information on other countries was not available.

Italy, Norway, the German Democratic Republic, United Kingdom, Sweden and South Africa. Of these, Austria, Denmark, Italy, Norway, the United Kingdom and Sweden come within the 'ratio' bracket 500-1 500. The Argentine, German Democratic Republic and South Africa are the least well placed of the remainder (7 900, 6 900 and 4 900 respectively), for fairly obvious geographical or political reasons; while the U.S.A must be considered separately in view of the fact that it has an extremely well developed internal system. In Category B there are also a number of anomalies, e.g, the Central African Republic, Indonesia, Libya, Pakistan, Egypt and the Sudan, all had 'ratios' below 200. The reason is probably that all have rather undeveloped internal systems (less than 2 telephones per 100 population), generally accompanied by a high degree of international interest in one direction or another. Where telephones have been installed in these countries, the likelihood of them being used for international calls may be greater than if telephone development were spread uniformly over the whole population.

Category C consists mainly of countries which are at present very inaccessible for the telecommunicator. To French Polynesia belongs the distinction of originating the least number of international calls for the countries listed and having the greatest ratio of national to international calls. We should be very careful about remedying this particular situation! Australia (16 000), Japan (8 100) and New Zealand (2 100), for example, are, however, very different cases. The first and third are among those countries with the highest degree of telephone development in the world (20·4 and 30·0 per 100 population in 1959 respectively) and Japan apparently has a calling rate per head of population about 50% higher than that of U.K, even though it has only about three-fifths as many telephones.

Many lessons may be drawn from the above statistics. Of great significance is the fact that none of the larger members of the British Commonwealth (with the exception of Pakistan) has a ratio of national to international calls lower than 400, and most are substantially higher. Perhaps it will be of very topical interest that five of the six members of the E.E.C have been placed in Category A, whilst only one of the 'Outer Seven' (Switzerland) is so fortunate. To the authors, however,



· PASSENGERS CARRIED
From various Board of Trade publications

⊙ PASSENGER—JOURNEYS
From H.M.S.O – Annual Abstract of Statistics

× PASSENGER—JOURNEYS
From British Transport Commission

△ LINE MILEAGE
From various Board of Trade publications

NOTES

1. *Passenger totals up to 1913 and line mileage up to 1862 include Ireland. Passengers in Ireland represented about 5·8% of the total in 1862, 2·6% in 1890, 2·2% in 1913.*
2. *Passenger figures up to 1876 include season ticket holders and exclude them 1876-1913. After 1913 different authorities used different methods of calculation, not necessarily related to the pre-1913 methods, for passenger-journeys.*

Fig.3. U.K railway traffic (passenger) and line mileage 1825-1960

the most striking lesson is that present facilities for long-distance telephone communication are, in the majority of cases, utterly inadequate for the needs of the world today and tomorrow.

3.3 COMPARISON WITH OTHER TYPES OF COMMUNICATION

With respect to the third approach, the growth diagrams in Figs.3 to 7 are illustrative. The first of these shows the number of passengers carried by railways in the United Kingdom from their inception to the present day, together with line mileage open. (The warning should be given that several sources have been used and the compilers of the statistics concerned have used several different methods, particularly in regard to exclusion or inclusion of season ticket holders and other passengers carried at reduced rates, or free.)

In the most interesting period from our point of view, however, from 1842-1910, there is reasonable consistency. The confused state of the data from 1914 to the present day is accounted for by disturbed political and economic conditions, and the increasing importance of other forms of transport. This also explains the fact that traffic has never returned to the previous growth curve, and has in fact declined, at times very steeply. The story as it stands is of considerable interest, giving a warning of what happens to a communications system (or any other system) when it fails to meet the needs of the time, in face of strong competition. The strenuous efforts made to offset the decline of the railways, in this country and others, have never yet done more than slow it down.

Table IV compares the growth in railway passenger traffic (with reference to 1829) with that of intercontinental telephone traffic (with reference to 1926). Table V shows the five-year growth rates.

These comparisons are interesting, particularly the 10^3 scaling factor in Table IV, but not necessarily meaningful in a quantitative sense (although refinements in technique might help to make them so). Points which could be taken into account include:

(a) Relative population increases in the two periods.
(b) Relative economic growth.
(c) The very different 'journey' lengths and destinations involved.
(d) Relative coverage of the communications requirement.

Table IV

COMPARISON OF U.K RAILWAY PASSENGER AND INTERCONTINENTAL TELEPHONE CALL TOTALS, IN INITIAL STAGES OF DEVELOPMENT

Year	1	6	11	16	21	26	31	34
Railway Passengers (millions)	–	6	18	35	64	100	150	185
Intercontinental telephone calls (thousands)	0·25	6·5	16	31	55	95	167	255

Table V

FIVE-YEAR GROWTH RATES, U.K RAILWAY PASSENGERS AND INTERCONTINENTAL TELEPHONE CALLS BEGINNING WITH THE SIXTH YEAR OF OPERATION

Period	1834–39	1839–44	1844–49	1849–54	1854–59
Railway Passengers Growth Rate	3	1·9	1·8	1·6	1·5
Period	1932–37	1937–42	1942–47	1947–52	1952–57
Intercontinental Call Growth Rate	2·5	1·9	1·8	1·7	1·75

All these considerations may well have militated against such rapid growth in the case of telephone communication, as there was in the railway 'boom'. By 1862, moreover, the railways had, by and large, solved the communications problem of the day and 60% of the line had been laid. Can we regard the world telecommunication network as being similarly complete at the present time?

The next three figures relate to growth of air passenger traffic. Fig.4 shows long-distance traffic from the U.K, over much the same period as we are concerned with. It is interesting to note that the curve shape is almost identical with that of Fig.1. The manner in which traffic returned to the curve, despite setbacks such as the 1939-45 war and the Comet

disasters, of the period around 1955, suggests that growth is following a natural law.

Fig.5 (British European Airways) demonstrates clearly what can happen when there are no major setbacks. A comparison of these last two diagrams with world-wide growth in civil air traffic (Fig.6) shows that British aviation may well claim to have a success story on its hands. B.E.A, for example, has multiplied its passengers by about 8 times 1948-61 and passenger-miles by about 9 times, as against the world traffic multiplications of about 6 and 7. B.O.A.C apparently hasn't done quite so well, corresponding figures being about 5½ and 6. This appearance is very probably illusory, however, since short-distance air travel, which will predominate in the I.C.A.O figures, has almost certainly expanded by a larger factor than long-distance.

Fig.7 shows U.K inland telephone traffic growth during the period 1913-60. A glance at the actual data (not the smoothed curve drawn

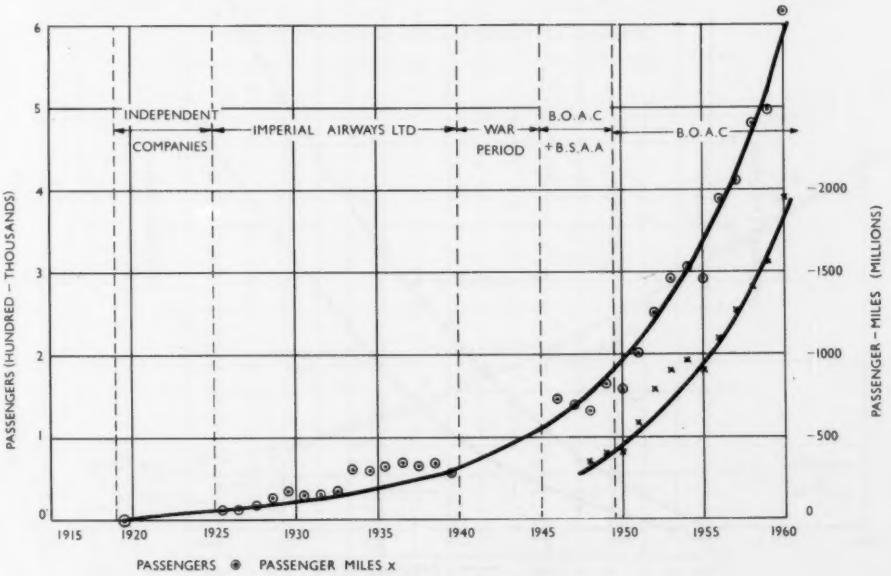


Fig.4. British long-distance air traffic 1918-1960

through it) shows that it does not even approach the form of the previous examples (Figs.1-6). But a little thought suggests good reasons for this:

(a) We are not looking at the initial growth period here—the first telephone exchange in this country was opened in 1879 and the first Post Office exchange in 1881.

(b) The period 1913-60 has been one of the most disturbed, economically and politically, in the history of the civilized world.

The implications of (a) are obvious—the broad lines of the inland telephone communication system had been more or less laid by 1913. What we would expect to see since then is a consistent growth due to

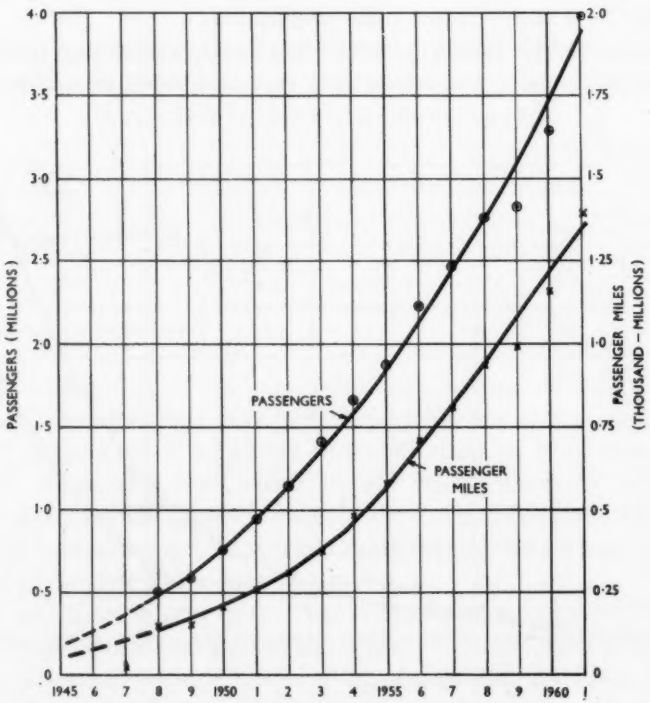


Fig.5. British European Airways traffic growth 1946-1961

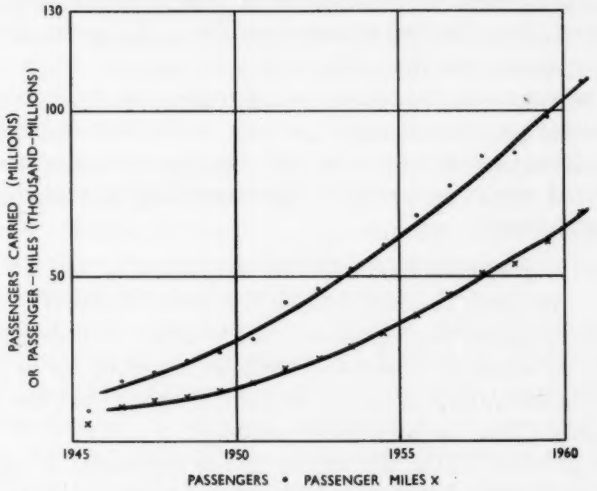


Fig.6. World civil air traffic 1945-1960 (I.C.A.O data)

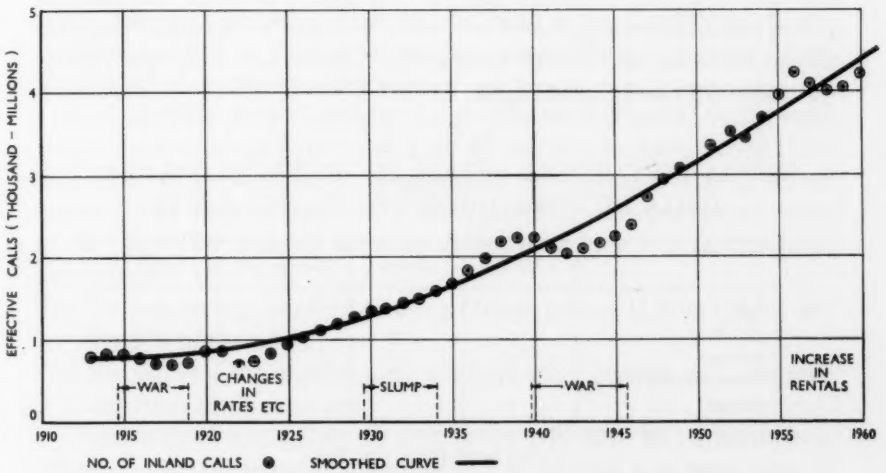


Fig.7. Numbers of U.K internal telephone calls (effective) 1913-1960

general improvement in economic well-being with, possibly, a more rapid growth over the last quarter-century as the great advances in detailed techniques had their effect.

It may be asked why the feature, so apparent in the previous examples, of rapid return to the 'natural' growth curves after wars and other disasters, did not occur in this case also. The answer is, almost certainly, that enforced restriction on capital investment has prevented growth to the natural pattern.

4 PREDICTED FUTURE EXPANSION OF INTERCONTINENTAL TELEPHONE TRAFFIC

Before proceeding to the logical conclusion of the preceding three sections (i.e, an attempt to use the methods described to estimate the growth of intercontinental telephone traffic over the next few decades), it is necessary to look at the current position.

This is given in Table VII, which shows estimates of the current annual long-distance call rate, world-wide, over transoceanic cables or radio systems.

It is this class of traffic for which the future world-wide communication network must provide. Several alternative systems, including a global satellite communication network, will have to be considered, and the decisions on the systems to be employed will be vitally affected by the traffic estimates that are used.

Table VII
ESTIMATED CURRENT TOTALS OF 'INTERCONTINENTAL' CALLS BETWEEN DIFFERENT 'ZONES' (000's)

	U.S.A	*Europe*	*Commonwealth*	*Foreign*
U.K	400	—	230	30
U.S.A	—	700	250	2 500[1]
Europe	—	—	100[2]	500[2]
Commonwealth	—	—	100	60
Foreign	—	—	—	125[2]

Grand total about 5 million

[1] includes Alaska, Hawaii, West Indies, etc [2] estimated in an arbitrary manner

For the purposes of Table VII, the world has been divided arbitrarily into five ' zones '. All sub-totals are based on actual data, using estimating procedure which can only have small error, with the exception of those marked [2]. (These were estimated by comparing the product of the number of telephones in the two zones concerned with those for other pairs of zones where the intercontinental traffic totals are known accurately.) This procedure is a little dangerous, in view of the wide variation that undoubtedly exists in the ratio of intercontinental calls to telephones for different countries, but the resultant total error is not likely to be large, since the sub-totals involved are fairly small.

The grand total is approximately 5 million calls, of which approximately 3·85 million are to or from the U.S.A and 1·17 million (including U.K-U.S.A and U.S.A-Commonwealth) are to, from or within the U.K and Commonwealth. It appears reasonable to suppose that average chargeable time per call is about 7½ minutes. Thus we arrive at a global figure of about 12·5 million 3-minute conversation units per annum.

It is certainly a matter of considerable difficulty to estimate future expansion accurately, from any or all of the three methods previously considered, without going into much more detail than the authors have been able to undertake. Nevertheless, bearing the limitations of the methods in mind, it is possible to make some informed guesses. These are related to the next twenty years.

Using the first method, we may simply take the U.K and U.S-originated traffic growth factors from Table I, for the last two decades, weight them according to present traffic magnitudes, and average. This gives an answer of 24, for a twenty-year growth factor. In assessing the accuracy of this figure for a global situation there are at least two factors to be kept in mind. They are :

(1) the inaccuracy involved in using factors for the U.K and U.S.A for the rest of the world ;
(2) the implicit assumption that multiplicative growth will continue for the period concerned.

There is little doubt that the first factor will have had a pessimistic effect on our calculation, since the U.S.A and the U.K were, for all except a few months of the period covered by the statistics, the only

major countries in which transoceanic telephone cables originated. They are also both countries with high telephone development—the rest of the world will, on average, undoubtedly catch up in this respect in future; certainly the U.S.A may, by comparison, be considered almost saturated in respect of telephones.

In any event, a country-by-country examination of intercontinental traffic growth factors over the last decade or two should be possible, and would remove the inaccuracy due to this first factor.

As to whether multiplicative growth will continue, we must look at the present need, which may be shown up in part by the second method, and attempt also to let historical analogies (Method 3) throw a little light on the situation. In this connection, it is worth noting that the installation of TAT-1, plus its subsequent expansion in capacity, has not nearly met the North Atlantic need. In the year ended 31st March, 1960, there were approximately 1½ million 3-minute conversation units between North America and Europe routed to, from or via the U.K. A simple calculation, allowing for the duration of the busy hours and the fact that paid time represents, at present, only about 25% of possible circuit occupancy, shows that TAT-1 could have handled only about one-half of these. The rest must have gone over radio circuits or possibly a small fraction over TAT-2. Current waiting times suggest that the situation has not materially improved in the intervening period—will it get any better, despite the coming of new cables, as radio circuit conditions worsen over the next few years?

One simple way of drawing conclusions from the second method is to take the U.K as an average case of inadequacy of international telecommunication. The ratio of national to international calls (Table IV) for the U.K in 1959/60 was 1 400. Comparing this with a 'desirable' datum of 300 for Category 'A' countries gives an immediate potential growth of 4·7. But intercontinental traffic from this country is certainly in a far worse position as regards facilities than continental traffic, which is ten times as great, and we may be considered to have at least as much interest, business and private, in the rest of the world as we have in Europe. Allowing for such factors as cost of a call, time differences and language difficulties, it may be that there is indeed an unsatisfied imme-

diate potential for a ten times increase in intercontinental telephone traffic from these islands. We must postulate additionally the extent of natural growth, as world-wide telephone development increases. It might not be unreasonable to put this factor at 10% per annum, or seven times in 20 years. Doing so we get an overall factor of 70 times from the second method. Again, a more detailed examination, using country-by-country or 'zoned' methods, ought to be possible.

The third method cannot be taken too seriously at present for quantitative prediction, although it may provide a general guide and a means of strengthening our faith! Supposing, however, we postulate that the natural growth of intercontinental telephone calls to and from these islands will be as great as that of internal railway travel in the 20-year

Table VIII

ESTIMATES OF INTERCONTINENTAL TELEPHONE TRAFFIC GROWTH FACTORS (NEXT 20 YEARS) OVER THE PERIOD 1960-80

Method	*Growth Factor*
1	24
2	70
2 and 3 combined	100

period 1842-62. The 1842 date is chosen because there is a rough analogy, in that the London-Birmingham line (the 'North Atlantic cable' of the railway system) was opened for traffic in 1837, five years previously. Thirty-four lines in all had been laid during the period 1829-42 and there was thus a fair degree of national coverage. Drawing on British railway history, there was a ten times increase in passengers from 1842-62. If this is associated with the factor of ten representing unsatisfied potential already derived, our analogy, crude as it is, results in a twenty-year growth factor of 100 times. The different growth factors, as derived from the three methods outlined above, are shown in Table VIII.

Summarizing, it may be thought that Method 1 is pessimistic, since it

assumes that the existing system is largely coping with the present need. Historical comparisons suggest that the assumption of multiplicative growth is justifiable. Perhaps greatest reliance may be placed on the result of the second method of approach, particularly if refined statistical techniques are used to strengthen its conclusions. The authors' preference is certainly for a twenty-year growth factor in the range 50-100. If we take a factor of 70, in conjunction with the estimate of current intercontinental telephone traffic of 12·5 million 3-minute units and the current London-New York charge of £1 per minute, we arrive at a figure for the annual income from an efficient global intercontinental telecommunications system, by 1981, of £2 625 000 000. This surely represents a glittering prize—or even half this amount, corresponding to a 50% reduction in rates, which might be required to achieve the necessary growth.

What we really need today is the faith in the future of our nineteenth-century ancestors, coupled with a certain degree of engineering and planning skill, in order to make sure that the facilities we lay down will not only meet the need during the next two decades but will be capable of adequate expansion during the following period.

5 CONCLUSIONS

We have attempted to suggest a philosophy of attack on an urgent problem, rather than propose an engineering solution. We can, however, attempt to carry matters a little further towards that solution.

There already exists a very good method of telecommunication between continents in the form of the transoceanic cable. However, if our arguments have been at all convincing, the view can be taken that cables and satellites can co-exist for quite a long time yet. The need is with us now; operational communications satellite systems may be 5 or 10 or even 15 years in the future. In this period let the cables unreel and perform their great service to humanity. Even from a parochial viewpoint as radio-communicators, we should not wish to stop this development. Communication, in its widest sense, is more important than technical arguments.

It may be, in this context, that we can learn a lesson for the slightly more distant future from the railways, which have served us for over a

hundred years. If the internal combustion engine had been invented before the steam engine, the world might not have its present huge and decaying railway system, nor need it. Roads are more flexible, aircraft systems potentially more flexible still. Is there an analogy between this and the cable versus satellite argument?

The ' trunk line ' conception in communications is well based. Analogous to it in nature is the tree, which draws from the ground (the subscribers) the material which it passes via its roots (the local lines) to the trunk, branches and leaves (distant subscribers' instruments). This, too, is a two-way system, and although we have no tangible fruits in telecommunications, fruits of one form or another may be there for the plucking. It may be that we do well to copy nature and should not, yet, depart too far from it to indulge in visionary schemes of satellite ' telephone exchanges '. There is one difference between a man-made communications system and a tree. The one is static and dies if it is moved without the greatest care, the other must be able to move, physically and with the times. A satellite system offers the opportunity of such mobility, a cable system does not.

There is one fundamental difficulty with the satellite communication concept. For it to be efficient, and to be developed and deployed in the most economical way, there must exist the highest degree of international co-operation. With all its faults, the HF radio system has one virtue, easily apparent—like a mirage! Two individuals, or organizations, who wish to communicate, in principle need merely to reach agreement on the technical details and set up their stations in working order. Apart from the ionosphere, there is nothing physical between them to give trouble. This virtue has become a vice, in the form of interference. Unless there is co-operation, the potential virtues of satellites may become vices also. Fortunately, however, the initial costs may be too large for all but a few States to meet, acting alone. Even if one decides to act alone, it will have to have the detailed agreement of all others with which it wishes to communicate. Moreover, it will be very dangerous to leave any other State out, for a satellite radio system may be jammed, without incurring unduly high technical or financial cost. Other ways in which it may be interfered with can be left to the imagination.

Acknowledgments

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HF Transmitters and Aerials – the Problem of their Interconnection

S. U. NOLAN, B.E, A.M.I.E.E

1 INTRODUCTION

AT HIGH FREQUENCY TRANSMITTING STATIONS used for long distance communications, the aerial arrangement depends upon the direction of service and the mode of propagation. Due to the diurnal variation in propagation conditions, and varying traffic demands brought about by world time differences, each aerial is used for a limited period of each day.

Transmitter utilization is not similarly restricted and there is therefore a requirement for a means of switching transmitters between a variety of aerials in a simple and reliable manner.

Basically the problem can be divided into three parts, as shown in Fig.1, that of transmission of the high power signals from the transmitter to a switching centre, the switching centre itself, and the transmission of the signal from this point to the aerial. In fact it is convenient to consider the evolution of such systems in the reverse order.

2 AERIALS AND TRANSMISSION LINES

Rhombic aerials are most frequently used for long distance communication in order to achieve high gain, high directivity and wide bandwidth economically. Since numbers of these large aerials are used, the first requirement is for a considerable length of feeder to connect the aerial and the central transmitter building. The efficiency of such a line is therefore of considerable significance. Two types are available, coaxial or balanced feeder. Since the aerials used require balanced excitation, and since the open wire balanced feeder is relatively very cheap, such feeders are almost universally used for this service. The loss per unit

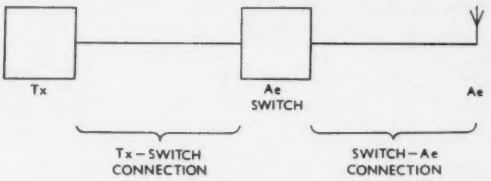

Fig.1. Basic arrangement

length, for a given conductor size and value of current, is fixed for a particular frequency. The power transmitted is proportional to the characteristic impedance, which is therefore made as high as possible by increasing the spacing between the two wires. Several factors lead to a characteristic impedance of 600 ohms as the optimum :

(i) Insulation losses, which increase with characteristic impedance.
(ii) Spacing of the conductors which increases rapidly with increases of impedance above 600 ohms.
(iii) The characteristic impedance of a rhombic aerial which, in the wideband form, is approximately 600 ohms.

While open wire feeders, being subject to weather hazards, require a greater degree of maintenance than coaxial types, the margin of economy in initial construction is so great that this is accepted.

Such feeders are, of course, unscreened and can therefore radiate and couple to adjacent feeders. However, for the normal balanced mode of transmission, the amount of radiation is negligible. The degree of coupling is also very small and does not increase linearly with line length, but varies sinusoidally, being maximum for parallel lines an odd multiple of a quarter wave long, and zero for even multiples. However, the line can also carry an unbalanced mode (which could be generated by any lack of symmetry in the system) where the conductors act as one, and the ground forms the return conductor. Coupling between transmitters in this mode is also small — assuming a generated unbalanced mode — 20 dB with respect to the balanced one, the inter-transmitter coupling will be at least — 40 dB.

The mode will radiate in uncontrolled directions, however, and so may cause interference and must therefore be closely controlled. This is

because the effective separation between the two conductors (the feeder wires and their images in the ground) may be a large fraction of a wavelength (for a feeder on 10-foot poles the equivalent spacing is a half-wavelength at 27 Mc/s). For a long straight run of feeder the radiation pattern will be highly directional and its maxima may be of comparable magnitude to the side lobes of the aerial. Fortunately, the mode will suffer considerable attenuation because of the poor conductivity of the ground. (It may be further attenuated by the circuit shown in Fig.2,

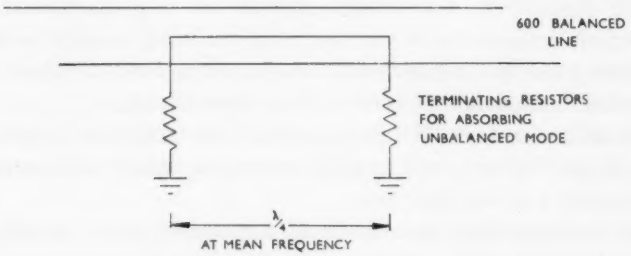

Fig.2. Method of absorbing unbalanced modes

where a centre wire is interposed for a quarter wavelength at the mean frequency, giving maximum coupling to the unbalanced mode for which it will act as a return conductor. It may be terminated to absorb the mode or made from magnetic stainless steel to give high attenuation.)

Within the transmitter building and in its vicinity, where the density of transmission lines is high, balanced open-wire feeder is undesirable because of the consequent hazard to personnel and the physical obstructions to movement and maintenance. (See Fig.3.) High radiation field within the building is also a considerable source of annoyance, particularly during measurement and maintenance procedures. Balanced feeders have, however, been inevitable, until recently, as a means for unbalance-to-balance conversion, at high power, did not exist.

Obviously the use of coaxial cable within the transmitter building has many advantages, especially as the cost factor is no longer of major significance in view of the short distances involved. In the absence of a

Fig.3. Large transmitting station showing arrangement of open wire feeders within the transmitter hall

Fig.4. Typical wideband highpower ferrite cored transformers

satisfactory means of unbalance/balance conversion at high power, binocular coaxial in a balanced arrangement has been used[1] but such a solution is still cumbersome and expensive. A fully satisfactory solution to the problem of transmitter-aerial communication has had to await the availability of high power wideband unbalance-to-balance transformers.

3 BALANCE-TO-UNBALANCE TRANSFORMATION

Transition from 600 ohm balanced feeder to 50 ohm coaxial can be effected in two ways:

(1) By an arrangement of transmission lines.

(2) By ferrite core transformers.

The design of transmission line transformers has been discussed in considerable detail.[2] A relatively complicated arrangement is necessary to effect the required transformation of mode and impedance level, and additional coaxial compensating stubs are required to produce a wideband design. Although the lines may be folded back on themselves to give a reasonably compact arrangement, the final design is nevertheless rather bulky, occupying a space approximately $12' \times 5' \times 3'$. It has therefore only limited attraction where it could most profitably be used—on those stations where a number of transmitters require connection to one of a larger number of aerials.

The situation has been alleviated by the recent availability of ferrite cored transformers capable of handling high power over virtually the whole of the HF band. These transformers are compact; typical examples are illustrated in Fig.4; the largest occupies a space of less than 2 feet in each direction (including insulators), and is capable of transmitting a power of 40 kW into a matched load (20 kW for an SWR of 0·5) over the frequency band of 4—27·5 Mc/s.

Two important considerations govern the design of this type of transformer:

(1) The impedance/frequency characteristic.

(2) The rating and efficiency of the transformer.

Over the middle reaches of the frequency band, the unit behaves as a tightly coupled transformer, giving $Z_1 = \left(\frac{N_1}{N_2}\right)^2 Z_2$ (See Fig.5.) At

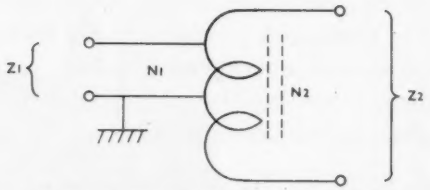

Fig.5. Unbalance-to-balance transformation

low frequencies the windings appear as shunt inductance, which can be compensated by series capacitors in the primary, secondary or both. At high frequencies, the leakage inductance and shunt capacity become important. In order to keep these factors within bounds, the transformer must be physically small and the turns few in number.

High efficiency (of the order of 98%) is therefore essential, as the power loss must be dissipated within a relatively small volume without excessive temperature rise (the effect of overload is to cause loss of ferrite permeability, when the transformer 'throws off' the load). Using an auto-transformer has a distinct advantage in this respect since the turns ratio is reasonably small, and the use of fewer total turns leads to shorter and better paths for escape of heat. Two kinds of ferrite loss occur: magnetic (hysteresis, eddy currents and magnetic domain friction) and dielectric. By screening the core, the latter can be reduced to a low value. The magnetic loss is approximately constant over the middle of the band but increases at high and low frequencies, constituting a limiting factor in wideband design.

The general factors governing the design of the transformer can be summarized as follows:

Low copper loss	few turns
Good Thermal conductance	few turns
Good HF response	few turns
Good HF power handling	few turns
Good LF response	many turns
Low ferrite loss at mid and low frequencies	many turns

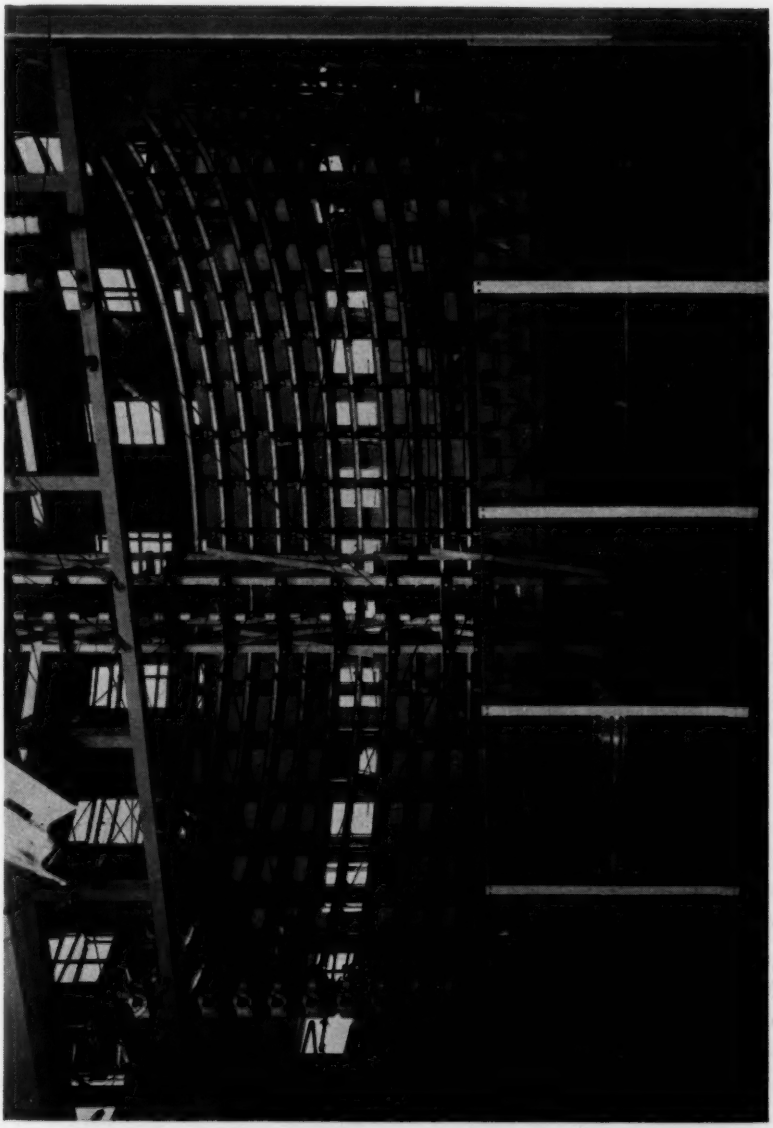

Fig.6. Typical 'Miller' aerial exchange

Where the highest power handling is required, the first requirements predominate and the number of turns that can be used is the irreducible minimum of 1 for the primary and 3 for the secondary, giving a ratio of 50 to 450 ohms. A schematic arrangement of such a device is shown in Fig.5 and a photograph of a complete unit in Fig.4. (The transition from 450 to 600 ohms is achieved by a tapered line a quarter-wave long at the lowest frequency.)

4 AERIAL COMMUTATION

The difficulties arising from switching of aerials at 600 ohms has been the major stimulus to the development of unbalance-to-balance transformers. The high voltages associated with high power transmissions involve considerable physical spacing between sections of the switch, while one pole is required for each transmitter that is to feed the aerial exchange. This results in a large and cumbersome device (see Fig.6) for which stringent safety regulations are necessary.

With the advent of high-power unbalance-to-balance transformers, a radical simplification is possible, using coaxial switches. A matrix can be constructed capable of connecting any of a number of transmitters to any one of a larger or smaller number of aerials. The most straightforward switching system is that in which any transmitter has access to any aerial. In such a system the basic operation, that of changing transmitter A from aerial X to aerial Y, must not interrupt any transmission other than that of B which is already connected to Y and must obviously be first removed from it. This may conveniently be effected by use of a matrix (see Figs.7 and 8) built up from a series of switches, each of which performs as a double change-over switch and has two positions, operated and non-operated; such a switch is shown in Fig.9. It carries two transmissions simultaneously with negligible coupling between them.

With such a system it is impossible to connect a transmitter to more than one aerial at a time or for that matter an aerial to more than one transmitter, but one can connect a given transmitter to a given aerial in a number of ways, only one of which, however, leaves the system free for all other transmitter-aerial combinations. This is the one using only

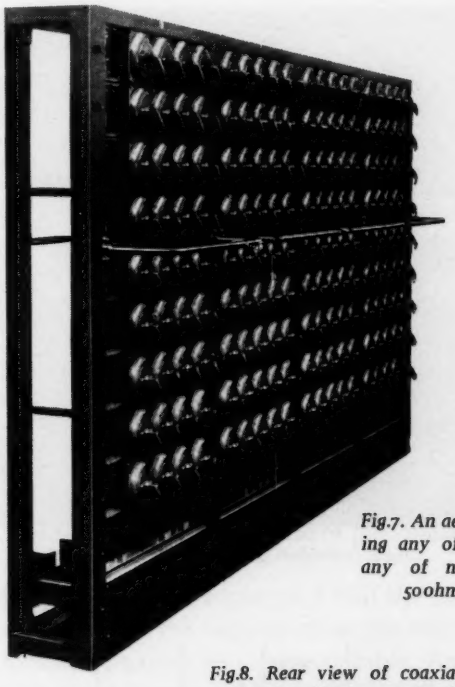

Fig.7. An aerial exchange connecting any of nine transmitters to any of nineteen aerials using 50ohm coaxial switches

Fig.8. Rear view of coaxial exchange (Fig.7) showing interconnection between switches

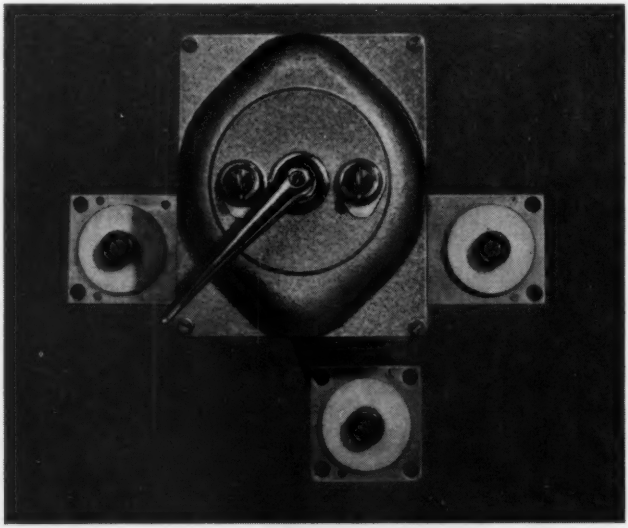

Fig.9. Individual 50ohm coaxial switch

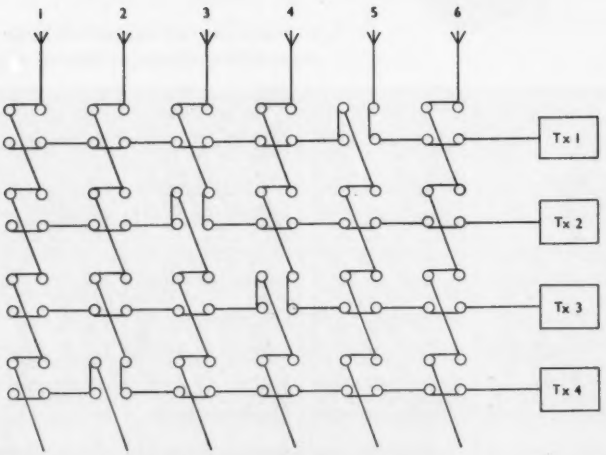

Fig.10. Schematic arrangement of coaxial exchange connection

one switch in the transmitter-aerial path in the operated condition. It is necessary, therefore, to restrict the switching to this method. This can be achieved by the use of key interlocks where every switch is fitted with two locks, one operated by a transmitter key and one by an aerial key, all keys being different. Each switch in the matrix is thus uniquely related to one transmitter/aerial combination and cannot be operated without their keys. (See Fig.10.) When operated, the handle traps the keys, which cannot be released until the switch is returned to the non-operated condition. One is therefore forced to operate the switches in the correct manner and sequence. Each switch is fitted with micro-switches, one set of which is connected to the transmitter HT interlock and trips the transmitter if it is operated on power, the other gives a remote indication of switch position.

The switch unit is 6 inches square. A 10×20 switch occupies an area $5' \times 10' \times 1'$, which is compact enough to be placed in any convenient position and be manually operated (though the mechanism is light enough to be operated by a simple electric or pneumatic motor if remote control is required).

The main drawback of such a system is that the number of switches is given by the product of the number of aerials and transmitters, and for large stations can amount to a large number. An economy in the number of switches can be effected by restricting the number of aerials available to each transmitter (i.e, breaking the universal switch down into a number of sub-universal systems). These can be interconnected to make all aerials available to some transmitters and all transmitters available to some aerials.

An alternative approach is to use a patching panel. In this method the transmitter feeders terminate in sockets arranged on a panel and the aerial feeders in flexible tails and plugs which can be connected manually to the transmitter sockets. The flexible jumper lead is made from $\frac{3}{8}$ inch diameter PTFE insulated coaxial cable. This will handle 10 kW at frequencies up to 27 Mc/s and SWR 0·5, and is the limiting factor in the power handling capacity of the system. The method is also limited in the number of transmitters and aerials it can handle as the leads become unmanageable above a limited number. The two methods, switching

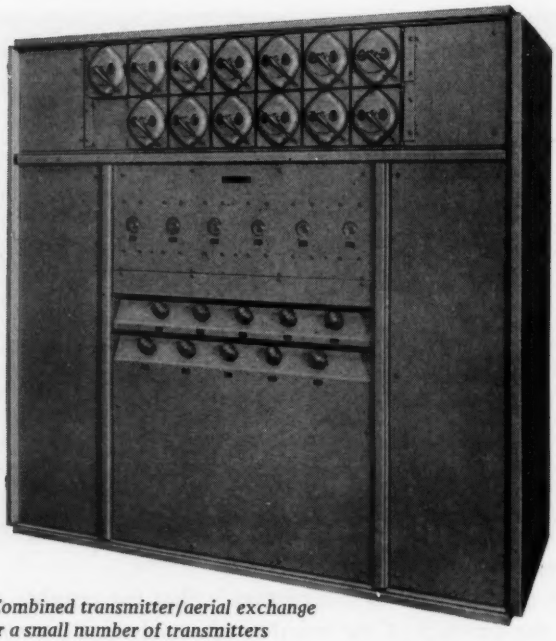

Fig.11. Combined transmitter/aerial exchange for a small number of transmitters

and patching, can be used in tandem, giving a hybrid system as in Fig.11, the low power transmitters being fed into the patching panel.

A comparison between Figs.6 and 7 speaks for itself as a comparison between the alternative approaches. (Fig.7 does not, of course, take account of the unbalance-to-balance transformers which are required for each aerial, but which can be mounted in any convenient location.)

5 CONCLUSIONS

Radical saving of space, and increase in safety and maintainability has been brought about by the advent of high efficiency ferrite cored transformers which have in turn permitted the development of a simple coaxial aerial switch matrix system.

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S. U. NOLAN was educated in Ireland and studied at University College, Dublin, where he gained his degree in Mechanical and Electrical Engineering in 1943. From 1944 to 1948 he worked on transmitter design for S.T.C when he joined Marconi's. From 1949 he has worked on aerial development and has been Chief of the Aerial Development Group from 1954.

On Means to Improve Frequency Stability

1 INTRODUCTION

THE PROGRESSIVE INCREASE in the utilization of the radio spectrum in recent years has led to a considerable interference problem. Although it is very important from this viewpoint that services should be kept within their assigned frequency bands—and this can generally be achieved with crystal controlled oscillators of quite modest stability—the accompanying pressure to reduce bandwidth occupancy has led to modulation methods which require very high frequency stability.

For telephony communication, the pilot carrier single-sideband system affords power economy and better intelligibility with less bandwidth requirement than amplitude modulation. With this transmission method, the low level carrier is filtered out at the receiver, amplified and used to lock the receiver oscillator. The bandwidth of the carrier filter has to be limited to about 150 c/s in order to separate the carrier from the lower modulation frequencies, a requirement which necessitates a high order of stability of the transmitted carrier frequency.

In some applications, particularly in network transmission where the possibility of AFC capture by a powerful interfering signal arises, complete suppression of the carrier is desirable, a stable carrier being re-inserted at the receiver. This demands an even greater degree of stability since a difference of frequency between the suppressed and re-inserted carriers of more than 30 c/s causes sufficient distortion to be objectionable even for commercial circuits using skilled operators. For a higher grade service, the difference should be even less.

For telegraphy, frequency shift keying is now well established, but the frequency shift is still far more than it needs be, leading to unnecessary frequency spread and a signal-to-noise ratio below the optimum ; for 100-baud transmission the frequency shift may probably be reduced to less than 200 c/s or less with some advantage. For this to be possible, the oscillators used for transmission and reception should have the same order of stability as for SSB telephony.

The two-tone telegraphy system, which generally offers improved performance over FSK, needs a similar order of stability while, for some proposed data transmission systems, even higher stabilities are required.

Extremely high stability is required when several transmitters operate on the same frequency, in order to cover a larger area effectively, in broadcasting or for a mobile service, for example. Two or more transmitters are strategically situated to cover the area, all working on the same nominal frequency. Clearly these transmitters must have accurately maintained frequencies if an intolerable flutter is to be avoided at places where signals are received with comparable strength from two or more sources. A difference in frequency between transmissions of up to one cycle per second can usually be tolerated, but a greater error is more than most receiver AGC circuits can deal with.

In order to meet the system requirements outlined above at the upper end of the HF band, it is necessary to design oscillators with stabilities ranging from about 1 part in 10^6 to a few parts in 10^8. Assuming use of quartz crystal control, there are three main groups of problems to be considered in this context. These relate respectively to control of the environment in which the crystal is to operate, to residual instability in the crystal itself and to the design of the remainder of the oscillator circuit. It is with a practical and economic solution to the first of these that this article is mainly concerned, although the second, in particular long-term drift of frequency with time, is a particularly baffling problem, and sometimes dictates the type of crystal to be used. It has been found in practice that AT or BT cut crystals for frequencies of about 5 Mc/s exhibit this ageing effect to the least extent. Even so, periodic adjustment to an outside standard is necessary for most types of stable oscillator.

2 CONTROL OF CRYSTAL ENVIRONMENT

The frequency of oscillation of a quartz crystal varies with temperature and for this reason it is usual to enclose the crystal in a temperature controlled oven, maintained at a temperature higher than the highest ambient temperature likely to be reached. The laws of variation of frequency with temperature for AT and BT cut crystals are respectively cubic and parabolic. Thus for each of these types there are temperatures at which the temperature coefficient of frequency is minimum or zero. It is possible by precise choice of the angle of cut to produce crystals having, within limits, predicted temperatures of minimum frequency change. The design procedure thus involves choosing a crystal with its point of minimum temperature coefficient matched to the temperature of the oven.

There are a few golden rules which govern the design of any temperature controlled crystal enclosure. The switching device used for temperature control must be in intimate contact with the heated surface in order to minimize temperature overshoots. The oven should incorporate a large thermal mass for the same reason. There will always be some heat loss from the crystal compartment and because of this, the stabilized temperature of the crystal will be slightly lower than the designed controlled temperature. The amount of the heat loss mainly determines how well the crystal will be protected from the effects of changing ambient temperature. A major source of heat loss is via the crystal leads and this is best minimized by making them of thin wire, preferably of poor heat conducting material such as eureka, and by deliberately conveying heat from the oven to those leads in order to reduce the temperature gradient between them and the crystal. It is, of course, important to reduce dissipation in the crystal itself as much as possible, since self heating can give rise to severe ageing effects in addition to temporary frequency changes. The circuit should therefore include some form of AGC which will ensure that the crystal oscillates at a low and constant level.

The choice of the method, or the design of the device, used for controlling temperature is of the greatest importance. Bi-metal contact breakers in general are insufficiently sensitive to provide a control better

than $\pm 1\,^{\circ}C$ and in this application a sensitivity at least ten times better than this is required. A contact thermometer can approach the required sensitivity but is a fragile device and in the past has suffered from contact trouble. A temperature-sensitive bridge arranged to balance at the required temperature and followed by a phase sensitive amplifier controlling the oven power via a relay, can be made as sensitive as is needed by varying the gain of the controlling amplifier. This is the method usually employed when extreme accuracy is required.

All these methods produce a final oven temperature which fluctuates above and below the required temperature and by an amount depending upon the precautions taken to minimize it. Even if proportional control is employed there must remain a small differential. There has, however, recently been developed an oven working on a principle which enables this differential to be reduced to negligible proportions, without the use of complicated external apparatus.

3 THE CHANGE-OF-STATE OVEN

One of the most stable things in nature is the melting point of pure crystalline substances. It is unchangeable save by large changes of pressure. (It requires a change of pressure of eight atmospheres to raise the melting point of ice by $\cdot 1\,^{\circ}C$.) If large pressure changes are avoided, the melting point of such a substance can be used as a temperature standard. Another advantage which derives from the use of a melting point as a temperature standard, is the thermal ballasting resulting from the property of latent heat of fusion. This leads to the valuable result that when a substance is partially melted any additional heat applied merely causes more of the substance to melt, the temperature remaining constant.

If we imagine a crystal embedded in the centre of a crystalline mass, with heat applied to the outer surface until some of the substance has melted, the temperature at the boundary between the liquid and the solid will be at the melting point. The crystal will thus be surrounded by an isothermal layer and, if there are no heat losses, the crystal temperature will rise to the melting point temperature. If more heat is applied, more of the substance melts, the thickness of the solid crystalline layer

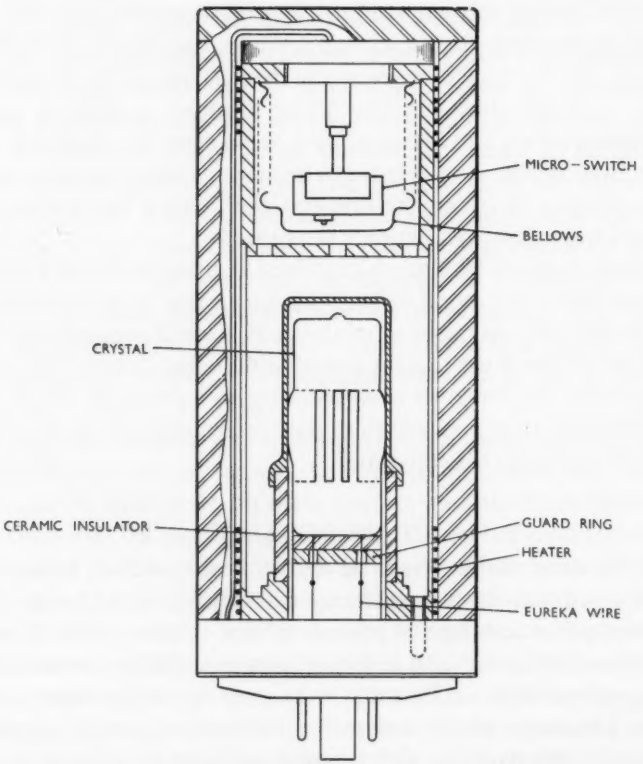

Fig.1. Sectional view of a change of state oven

surrounding the crystal diminishes but the crystal temperature stays at the melting point so long as the solid layer remains.

In order to make a practical oven using this principle, means have to be devised whereby the proportion of liquid to solid is maintained approximately constant. This is done by making use of another physical property of most crystalline materials, that of expansion with change of state. This expansion, with some substances, is considerable and can be used to operate a bellows which in turn operates a micro-switch to control the power supplied to the oven.

The chosen crystalline filler is napthalene, which melts at 79·5°C, is chemically stable and does not attack metals. It expands by about 12% in volume on melting.

Fig.1 shows a sectional view of a change-of-state oven. The crystal is mounted on a holder, designed to minimize heat loss. Surrounding it is a brass tube closed at one end, fitted over a ceramic insulator which is in turn fixed to the end face of the oven. Concentric with this is an outer brass cylinder carrying the heater winding. A metallic bellows is enclosed within an extension of the outer cylinder, the inner face of which is perforated to allow the filter to surround the bellows. Within the latter is a microswitch, spring mounted to ensure that it will not be damaged during overshoot. Connections from the heater winding to the microswitch are taken via its supporting pillars and there is also a small hole to prevent build-up of air pressure within the bellows. The crystal envelope, seated on a felt pad, is held by the fingers of a beryllium copper shield (Fig.1) which is fixed to a relatively heavy brass guard ring. Heat is then conveyed from the crystal chamber to the guard ring, thereby reducing the temperature gradient along the crystal lead-out wires. The whole assembly is mounted on a tufnol base, carrying an octal plug to which all leads are connected. The oven cover is also fixed to this base and the space between the cover and the oven is filled with felt.

Fig.2 shows a photograph of a completely assembled oven together with a separate crystal and holder. The dimensions of the oven are 6″ long × 2½″ diameter.

In the evolution of this design, calculations were made of the various thermal capacities involved, and the masses of the sections used were adjusted to provide as far as possible, uniform thermal capacity per unit length. Heat losses are rather greater at the end of oven remote from the bellows. Thus the bellows end is the first to reach the melting point on heating and the last to reach the solidifying point on cooling, a condition which is obviously desirable for free operation.

In contrast with the control apparatus associated with a bridge controlled oven, the external connections to a change-of-state oven are extremely simple. The only requirements are a mains transformer providing about 30 W at 30 V, a fuse and an indicating lamp to show that

switching is proceeding normally. Actually 30 W is a greater power than is needed except in the interests of a quick warm up from cold. The latent heat ballasting effect is so good that it is unnecessary to keep the heating power low to avoid temperature overshoot trouble.

4 PERFORMANCE

The switching cycle of the oven is approximately 20 seconds On and 80 seconds Off. A 5 Mc/s crystal oscillator employing the oven reaches a frequency within 1 part in 10^7 of its final frequency within 35 minutes.

The effect of oven cycling on frequency is completely negligible for most practical purposes. The extent of temperature variation within the oven has been measured at ± 0014°C, which, assuming that the crystal has the rather poor temperature coefficient of frequency of 5 parts in 10^7 per °C, would cause a frequency deviation of ± 7 parts in 10^{10}.

The effects of ambient temperature changes on crystal frequency are

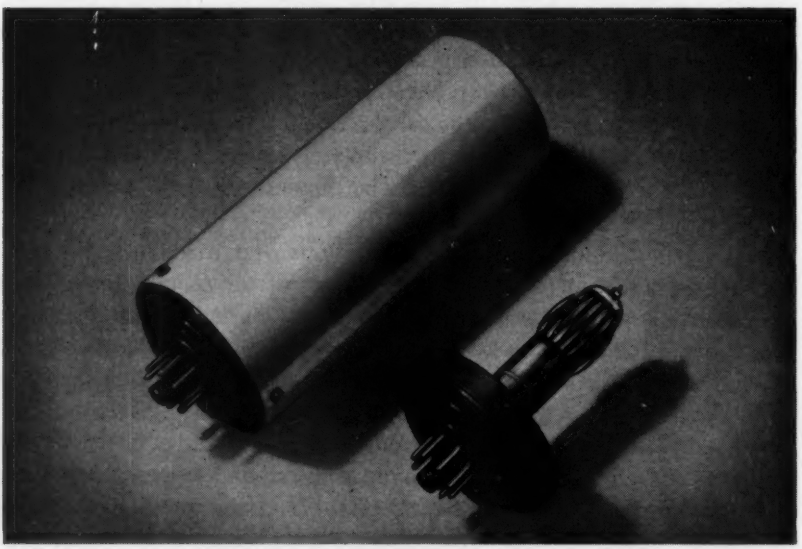

Fig.2. Change of state oven and crystal holder

reduced by approximately 700 times by the use of the oven. Thus, assuming again 5 parts in 10^7 as the crystal temperature coefficient, a 10° change in ambient temperature would produce a frequency shift of 7·2 parts in 10^9.

The great advantage of the change-of-state oven over other types is that its excellent performance is achieved by virtue of its own physical properties, needing no external electronic additions. It should therefore be extremely reliable.

Since the only component liable to breakdown is the microswitch, an item not normally associated with extreme reliability, life tests have been carried out on the switches used. In these tests which are still continuing, six of these switches have survived 45000000 operations without a failure. At the oven switching rate of one operation per 100 seconds, this suggests that the switches should still be operating after at least 14 years' service.

Because of the absence of external controlling circuitry, the cost should be considerably less than that of any other oven of similar performance.

Radio & Electronics Industry Awards

FOR PUBLISHED TECHNICAL ARTICLES

EACH YEAR six premium awards are made to authors whose articles, appearing in British technical journals, are considered to have best set out British achievement in the electronics field.

Point to Point Telecommunications featured in these awards for the first time in 1960, with the article 'A Tropospheric Scatter Link over a 200 mile Path', by G. L. Grisdale and D. A. Paynter (*Point to Point Telecommunications*, Vol. 5, Number 1, October 1960).

Dr Grisdale is seen (above) receiving the award, on behalf of himself and his co-author, from Sir Harold Bishop, Director of Technical Services, the British Broadcasting Corporation.

Fur unsere deutschsprechenden Leser veröffentlichen wir eine kurze Abfassung in deutscher Sprache von den Aufsätzen, die in dieser Ausgabe erscheinen.

SEITE 2

STANDPUNKTE

Soweit in den Heften der *Point to Point Telecommunications* seit deren Einführung vor 5 Jahren ein Thema wiederholt behandelt wurde, betraf dies die Tatsache, dass die Bereitstellung von Fernsprecheinrichtungen sowohl auf nationalem als auch internationalem Gebiet seit vielen Jahren hinter der zur Verfügung stehenden Technik herhinkte. Kapitalmangel bildete oft die Haupteinschränkung. Dies mag jedoch teilweise in der ungerechtfertigt konservativen Einstellung der planenden Stellen bei der Abschätzung des Bedarfs begründet sein. Diese Ansicht wird zumindest teilweise durch die Fernsprechentwicklung in den Vereinigten Staaten untermauert, wo solche Einschränkungen nicht bestehen. Das Ergebnis ist ein Fernsprechnetz, welches in der gesamten Welt (mit der möglichen Ausnahme von Schweden) nicht seinesgleichen hat.

Auf Grund der Erfahrung mit dem transatlantischen Kabel TAT-1, bei dem die Nachfrage laufend die optimistischsten Vorhersagen soweit übertraf, dass ein Kanalabstand von 3kHz und jetzt auch TASI angewendet werden musste, müssen wir annehmen, dass dieser pessimistische Geist bei der Planung für die zukünftige Entwicklung des interkontinentalen Netzes immer noch besteht.

Ein neuerlicher Ausbruch dieses Pessimismus betrifft die Verbindungen über Erdsatelliten. Es werden immer noch Argumente vorgebracht, dass Erdsatelliten bei der Erweiterung des Koaxialkabalnetzes mit Verstärkern nicht benötigt werden. Wir glauben jedoch, dass die Entwicklung des interkontinentalen Fernsprechverkehrs über das allgemein erkannte Mass hinaus durch Beschränkungen der Kanalkapazität und der Betriebsqualität gehemmt worden ist. Eine Analyse nicht nur des Fernsprechverkehrs sondern auch der Entwicklung auf anderen Gebieten der Fernmeldetechnik legt den Gedanken nahe, dass die vorgeschlagene Entwicklung für die Zeit bis 1980 sogar bis zu einer 10ner Potenz zu pessimistisch ist. Eine der Hauptschwierigkeiten ist die Abschätzung des Verkehrsverlustes als Folge zu grosser Wartezeiten im Fernsprechverkehr. Wir nehmen an, dass ein Verlust von weniger als einer Stunde gerade noch annehmbar ist, jedoch mit Ungeduld. Wenn jedoch die Wartezeit mehr als eine Stunde beträgt, dann wird sich der Verkehr auf andere Übermittlungsverfahren, wie Fernschreiber und sogar Luftpostbriefe, verlagern. Wo der Luftpostverkehr gut eingespielt ist, die Fernsprechmöglichkeiten jedoch schlecht sind, glauben wir, dass eine beträchtliche Verkehrsnachfrage besteht, weil zur Zeit viele Leute noch nicht einmal die Möglichkeit eines Ferngespräches in Erwägung ziehen.

In vieler Hinsicht befindet sich das Welt-Fernsprechnetz in einem kritischen Entwicklungsstadium. Ein vernünftiger Optimismus könnte im Laufe der nächsten 20 Jahre zu einer Erweiterung führen, deren Ausmass viel grösser ist, als unseres Wissens geschätzt wird.

SEITE 4

EINE VORAUSSCHAU AUF DIE ZUKÜNFTIGE ENTWICKLUNG DES INTERKONTINENTALEN FERNSPRECHVERKEHRS

von M. Telford und G. A. Isted

Die Fernmelde-Ingenieure sind sich im allgemeinen darüber einig, dass unser gegenwärtiges System des Funk-Weitverkehrs nicht nur seine Grenze erreicht hat, sondern auch so stark von Naturerscheinungen abhängt, dass damit die von den Benutzern heutzutage geforderte hohe Betriebsqualität nicht erreichbar ist. Nach heutigen Normen ist ein typischer Fernsprech- Weitverkehrskanal bestenfalls eine Schmalbandübertragung. Damit können nicht mehr als 4 Einseitenband-Fernsprechkanäle übertragen werden. Weiterhin muss für einen beträchtlichen Zeitanteil vielfach mit einem Betriebsausfall gerechnet werden. Obwohl die Ein-

führung des transozeanischen Fernsprechkabels die Lage auf mehreren Hauprouten geändert hat, besteht jedoch kein Zweifel, dass wir auf dem Gebiet der Fernmeldetechnik bei einer kritischen Entscheidung angelangt sind und dass nur eine revolutionäre Änderung der Technik und der Einrichtungen die Erfüllung des zukünftigen Bedarfs ermöglichen kann.

Bevor ein Vorschlag über die durchzuführende Umwälzung gemacht werden kann, muss man zunächst das Ausmass des in absehbarer Zukunft zu erwartenden Anwachsens des Fernmeldeverkehrs betrachten. Für diese Zwecke wurden drei statistische Methoden angewendet. Bei der ersten Methode wird die uns betreffende Weitverkehrsart graphisch aufgetragen und deren Anwachsenuntersucht. Abb.1 gibt als Beispiel de jährgiche Anzahl der Ferngespräche wieder, die seit 1927 von Grossbritannien aus nach aussereuropäischen Ländern über Kurzwellen-Funkstrecken geführt wurden. Die letzte Angabe enthält Gespräche, die über das erste transatlantische Kabel (TAT-1) geführt wurden. Die Gleichmässigkeit der durch die Punkte gezogenen Kurve ist in den Zeiten eines natürlichen Anwachsens ohne Behinderung durch Störungen, die ausserhalb des technischen Einflusses liegen, sehr interessant. Ebenso interessant ist die Geschwindigkeit, mit der die Kurve beim Verschwinden äusserer Beschränkungen zu der ursprünglichen Kurve zurückkehrt. Man erkennt zwei grössere Unregelmässigkeiten. Eine lässt sich offensichtlich auf den Krieg von 1939-45 zurückführen und die zweite liegt in dem Zeitraum von 1952-7. Ein Sonnenfleckenminimum dauerte etwa von Mitte 1951 bis Mitte 1955 und es besteht kaum ein Zweifel, dass dessen nachteilige Wirkungen auf den Funkverkehr eine Hauptursache des Knicks in der Zeit von 1952-7 ist und zwar wegen der reinen Unzulänglichkeit des Funkdienstes in der Bewältigung der Verkehrsanforderungen, sowohl quantitativ als auch qualitativ. Nach dem Einbau des transatlantischen Kabels TAT-1 war die Anzahl der Nordatlantik-Gespräche von Grossbritannien aus in dem am 31. März 1960 endenden Jahr dreimal so hoch wie in dem am 31. März 1956 endenden Jahr, während die Zahl der von den britischen Inseln ausgehenden internationalen Funkgespräche nur um ungefähr 65% angestiegen ist. Es bestehen keine Anzeichen für ein Nachlassen im Anwachsen des Nordatlantik-Verkehrs. Wartezeiten von mehr als einer Stunde treten gewöhnlich während der Hauptverkehrszeit auf, trotzdem die Anzahl der auf dem Kabelweg zur Verfügung stehenden Kanäle seit der Inbetriebnahme des Kabels mehr als verdoppelt worden ist.

Die Regelmässigkeit des Anwachsens des Fernsprechverkehrs und die Leichtigkeit, mit der grössere Abweichungen von dieser Entwicklung erklärt werden können, gestattet einige einfache Schlussfolgerungen. Die Tabelle 1 gibt die aus den Angaben in Abb.1 gewonnenen Zahlen für die Anwachsgeschwindigkeit wieder. Ausserdem sind in den in Abb.2 wiedergegebenen Zahlen die von den U.S.A ausgehenden Gespräche enthalten. Daraus ersieht man, dass die in den letzten 30 Jahren von Grossbritannien und von den U.S.A ausgehenden Gespräche sich um 66bzw. 117mal vervielfacht haben.

Bei der zweiten Lösungsmethode wird ein Vergleich zwischen dem interkontinentalen Fernsprechverkehr und anderen Arten des Fernsprechverkehrs, wie Gespräche innerhalb nationaler Netze gezogen. Die Ergebnisse sind in den Tabellen 2 und 3 wiedergegeben. In der Tabelle 3 sind alle Länder, von denen statistische Angaben der gewünschten Art zur Verfügung standen, in drei Gruppen unterteilt worden: (A) Länder mit guten Fernsprechverbindungen nach dem Ausland, (B) Länder mit mässigen und schlechten Fernsprechverbindungen nach dem Ausland und (C) Länder mit hauptsächlich Kurzwellen-Funkfernsprechverbindungen für den Fernsprechverkehr nach dem Ausland. Diese Angaben zeigen wahrscheinlich am auffälligsten, dass die gegenwärtigen Einrichtungen für den Fernsprech-Weitverkehr in den meisten Fällen für die Anforderungen in der heutigen und späteren Welt vollkommen unzulänglich sind.

Die dritte Lösungsmethode basiert auf einer statistischen Untersuchung des Schicksals anderer Fernmeldearten. Die Ergebnisse sind in den Abb.3-7 in graphischer Form wiedergegeben. Die erste Abbildung gibt die Zahl der von den britischen Eisenbahnen seit deren Einführung bis heute beförderten Personen wieder und enthält Angaben über die zur Benutzung zur Verfügung stehende Streckenlänge. Die verworrenen Angaben in der Zeit seit 1914 haben wahrscheinlich ihren Grund in den gestörten, politischen und wirtschaftlichen Verhältnissen und in der wachsenden Bedeutung von anderen Transportmöglichkeiten. Es kann als Warnung dafür dienen, was einem Fernmeldenetz zustossen kann, wenn es bei gleichzeitigem starken

Wettbewerb nicht die Bedürfnisse der Zeit befriedigt. Wenn die verschiedenen Verkehrsformen miteinander verglichen werden, dann muss man unbedingt die zueinandergehörigen Entwicklungszeiträume auswählen. Dies wurde in den Tabellen 4 und 5 durchgeführt und es scheint, dass die Entwicklung in den beiden Verkehrsformen sehr ähnlich verläuft.

Abb.4 zeigt das Anwachsen des Passagierflug-Fernverkehrs von Grossbritannien aus und zwar für den uns interessierenden Zeitraum. Es ist interessant festzustellen, dass die Form der Kurve fast vollkommen mit der in Abb.1 gezeigten Kurve übereinstimmt, während die Art, mit der sich der Verkehr nach Rückschlägen durch den Krieg von 1939-45 und durch die Comet-Flugzeugunglücke in der Zeit um 1955 der Kurve wieder annähert, den Gedanken nahelegt, dass das Anwachsen einem natürlichen Gesetz folgt.

Bevor man mit der Benutzung der beschriebenen Methoden zur Abschätzung des Anwachsens des interkontinentalen Fernsprechverkehrs in den nächsten Jahrzehnten fortfahren kann, muss man die gegenwärtige Lage untersuchen. Dies geschieht in Tabelle 7, in der Schätzungen über die Zahl der gegenwärtigen jährlichen Ferngespräche über transozeanische Kabel und Funkverbindungen wiedergegeben sind. Zur Vereinfachung wurde die Welt willkürlich in 5 Zonen unterteilt. Die Gesamtzahl beträgt ungefähr 5 Millionen Gespräche. Die durchschnittliche angerechnete Gesprächszeit kann man wohl mit ungefähr 7½ Minuten annehmen. Damit kommen wir auf eine gegenwärtige Welt-Verkehrszahl von ungefähr 12½ Millionen 3-Minuten Gespräche pro Jahr. Die geschätzten Zahlen für das Anwachsen des Verkehrs in den nächsten 20 Jahren auf der Basis der drei angegebenen Methoden sind in Tabelle 8 wiedergegeben. Bei Annahme eines durchschnittlichen Anwachsfaktors von 70 in Verbindung mit der Schätzung des gegenwärtigen Welt-Fernsprechverkehrs bei einer Gebühr von £1 pro Minute kommt man auf ein jährliches Einkommen von £2625000000 Sterling im Jahre 1981 aus einem wirtschaftlich arbeitenden Welt-Verkehrssystem.

Ein Glaube an die Zukunft in Verbindung mit technischem Wissen und guter Planung ist nötig, um zu gewährleisten, dass die von uns geschaffenen Einrichtungen nicht nur den Bedarf der nächsten beiden Jahrzehnte befriedigen, sondern auch später angemessen erweitert werden können.

SEITE 32

KURZWELLEN-SENDER UND ANTENNEN DAS PROBLEM DER GEGENSEITIGEN VERBINDUNG

von S. U. Nolan

Bei Kurzwellen-Sendern für den Weitverkehr hängt die Anordnung der Antennen von der Anzahl und der Dauer der Betriebsdienste ab. Die Ausnutzung der Sender ist nicht in ähnlicher Weise begrenzt. Aus diesem Grunde müssen die einzelnen Sender mit verschiedenen Antennen verbunden werden, wenn man sie voll ausnutzen will. Das Problem der Verbindung von Sendern und Antennen kann in der in Abb.1 gezeigten Weise in drei Teile unterteilt werden.

Für den Weitverkehr werden meistens Rhombus-Antennen benutzt und da diese grosse Abmessungen haben, werden für die Verbindung zwischen den Antennen und dem Sendergebäude lange Speiseleitungen benötigt. Da Rhombus-Antennen symmetrische Speiseleitungen benötigen und oberirdische Übertragungsleitungen verhältnismässig billig sind, werden diese oberirdischen Leitungen fast ausschliesslich zu diesem Zweck benutzt. Ein Wellenwiderstand von 600 Ohm wird allgemein als vernünftiger Kompromiss zwischen den widersprechenden Faktoren gewählt.

Innerhalb des Sendergebäudes, wo die Anzahl der Übertragungsleitungen hoch ist, sind symmetrische Speiseleitungen unerwünscht und zwar wegen der physikalischen Schwierigkeiten und der Gefahr von hohen Hochfrequenzspannungen (siehe Abb.3). Ausserdem macht das starke Strahlungsfeld Messungen und Pflegearbeiten an den Sendern zu einem schwierigen Problem. Symmetrische Speiseleitungen waren jedoch unvermeidbar, da ein geeignetes Mittel für eine Symmetrierschaltung bei hohen Senderleistungen nicht zur Verfügung stand.

Ein Übergang von einer unsymmetrischen 50 Ohm-Leitung auf eine symmetrische Leitung mit 600 Ohm Wellenwiderstand kann natürlich durch eine Schaltung mit Leitungsstücken, welche sehr viel Raum beansprucht, oder mittels eines Transformators mit Ferritkern durchgeführt werden. Die Tatsache, dass nunmehr diese Transformatoren zur Verfügung stehen, hat die ganze Lage im wahrsten Sinne des Wortes transformiert. Typische

Beispiele werden in Abb.4 gezeigt. Die grösste dieser Anordnungen kann eine Sender-Ausgangsleistung von 20kW bei einem Wellenspannungsverhältnis von 0,5 übertragen und benötiht dabei einen Raum, dessen Abmessungen in jeder Richtung kleiner als 70cm sind. Der Bau dieser Transformatoren, welcher durch die Probleme der Antennenumschaltung bei einem Wellenwiderstand von 600Ohm angeregt worden war, erlaubt eine radikale Verbesserung gegenüber der z.Zt. angewendeten Technik. Diese Entwicklung fand ihren Niederschlag in dem in Abb.6 gezeigten 'Miller'-Antennenschalter. Bei Benutzung dieser Transformatoren kann die Hochfrequenzenergie innerhalb des Sendergebäudes durch niederohmige Koaxial-Speiseleitungen übertragen werden und die Antennenumschaltung kann auf diese Weise durchgeführt werden. Dies führte zu der Entwicklung von einfachen Koaxial-Umschaltern, die in Form einer Matritze angeordnet werden können (siehe Abb.7, 8, 9 und 10). Die hier im besonderen gezeigte Konstruktion enthält eine Sperrschaltung mittels Schlüsseln, wodurch eine narrensichere Verbindung zwischen Antennen und Sendern gewährleistet wird. Die Symmetrierung wird am antennenseitigen Ende des Schalters durchgeführt, wobei wie bisher oberirdische Speiseleitungen für die Verbindung zu den Antennen benutzt werden.

Dadurch, dass ein geeignetes Mittel für die Transformation der Hochfrequenzenergie zur Verfügung stand, konnten Koaxial-Antennenschalter entwickelt werden. Die beiden neuen Methoden erlauben eine radikale Vereinfachung bei der Bearbeitung dieses Problems.

SEITE 46

MITTEL ZUR VERBESSERUNG DER FREQUENZSTABILITÄT

Obwohl normale Kristalloszillatoren zur Vermeidung von Störungen zwischen benachbarten Frequenzen ausreichen, erfordern einige moderne Modulationsmethoden, die zur Erzielung eines verbesserten Weitverkehrs angewendet werden, eine Frequenszstabilität von $1{:}5{\cdot}10^7$ oder besser. Solche Systeme umfassen die Einseitenbandübertragung mit unterdrücktem Träger und Trägersynchronisierung für Telephonie, sowie die Frequenzumtastung für Telegraphie.

Für diese Zwecke müssen Kristalle gewählt werden, die gute Alterungseigenschaften besitzen und deren Temperatur in einem Bereich von weniger als 0,1°C konstant gehalten wird. Kristallöfen hoher Stabilität werden im allgemeinen durch eine Temperatur-Brückenschaltung gesteuert, auf die ein phasenempfindlicher Verstärker und ein Relais folgt. Diese Schwierigkeiten können durch die Verwendung einer neuen Ofentype vermieden werden, welche den Schmelzpunkt einer kristallinen Substanz für die Temperaturstabilisierung ausnutzt. Die Eigenschaft der Erstarrungswärme kann mit Vorteil als termische Impedanz gegen zyklische Temperaturschwankungen als Folge der Ofenumschaltung ausgenutzt werden. Dabei wird die Eigenschaft der Raumausdehnung bei dem Schmelzvorgang zur Steuerung der Wärmezufuhr zum Ofen benutzt.

Abb.1 zeigt einen Teil eines solchen Ofens auf der Basis der Zustandsänderung. Der Kristall ist in einem Schutzring auf einem thermisch-isolierten Halter angebracht und wird von einer Seite her in die innere Kammer eingeführt. Am anderen Ende befindet sich ein biegsamer Faltenbalg aus Metall, der einen Kleinstschalter zur Steuerung der Ofenwärme betätigt. Das Innere des Ofens ist mit Naphtalin gefüllt, welches einen Schmelzpunkt von 79,5°C hat und dessen Volumen sich bei dem Schmelzvorgang um 12% ausdehnt. Die durch eine Heizwicklung auf der Aussenseite des Ofens zugeführte Wärme schmilzt eine Schicht der Füllung, welche die Kristallkammer umgibt. Dadurch wird der Faltenbalg freigegeben, der die Wärmezufuhr abschaltet, wenn ein bestimmter Betrag der Füllung geschmolzen ist.

Technische Daten

Ofenheizung: 30W

Schaltzyklus: 20 Sekunden ein, 80 Sekunden aus

Anheizzeit: 35 Minuten für eine Stabilisierung von $1{:}10^7$

Zyklischer Fehler: $\pm$0,0014°C oder $\pm 1{:}7{\cdot}10^{10}$ für einen Kristall mit einem Temperaturkoeffizienten von $1{:}5{\cdot}10^7$ pro °C

Presentamos este sumario de los articulos publicados en este nùmero, redactado en castellano especialmente para nuestros lectores de habla castellana.

PAGINA 2

PUNTOS DE VISTA

Dentro de los temas que se han reiterado en *Point to Point Telecommunications* desde que fué lanzada cinco años atrás, está el que el suministro de facilidades para los servicios telefónicos, tanto nacionales cuanto internacionales, ha estado atrasado durante muchos años con respecto a la demanda existente en potencia. En muchos casos la falta de capital ha sido el impedimento principal, pero ésto puede haberse debido almenos en parte a que los proyectistas mimos fueron demasiado conservadores en sus cálculos de la demanda. Esta opinión está respaldada (parcialmente, por lo menos) por el desarrollo del teléfono en los EE. UU. de N. América donde no existió tal impedimento, con el resultado que se dispone allí de una red telefónica sin par en el resto del mundo (con la posible excepción de Suecia).

Pese a las experiencias con el cable transatlántico TAT-1, donde la demanda ha sido siempre mayor que lo previsto en los pronósticos más optimistas, a tal punto que se ha tenido que recurrir a la canalización de 3Kc/s y ahora a TASI, sospechamos que este espíritu de pesimismo persiste aún al proyectarse el desarrollo futuro de la red intercontinental.

La manifestación más reciente de este pesimismo se relaciona a las comunicaciones por satélites. Se está arguyendo aún que con el aumento de los cables coaxiles con repetidores podrá prescindirse de los satélites. No obstante, nosotros opinamos que el desarrollo del tráfico telefónico intercontinental ha sido frenado aún más de lo que se supone generalmente por las limitaciones de capacidad y calidad del servicio. Un análisis no sólo del tráfico telefónico sino del desarrollo de otros medios de comunicación hace pensar que el tipo de desarrollo que se está proyectando será pesimista en grado sumo durante el período que alcanza hasta el año 1980. Uno de los problemas más difíciles deriva del cálculo de tráfico perdido debido a demoras excesivas en las comunicaciones telefónicas. Se nos ocurre que, cuando la demora es menor de una hora, ésta será tolerada—aunque de mala gana—pero que donde hay que esperar más de una hora habrá un desvío del tráfico hacia otros medios de comunicación, como ser el télex o aún las cartas por vía aérea. Allí donde los servicios postales por vía aérea son eficientes, a la vez que las facilidades telefónicas son indiferentes, sospechamos que hay una importante demanda de trafico en potencia porque la gente actualmente ni siquiera piensa en la posibilidad de realizar llamadas telefónicas.

Por muchas razones la red mundial de teléfonos a larga distancia se halla en una etapa crítica de su desarrollo; un espíritu de optimismo razonado podría conducir a un nivel de expansión en los próximos 20 años mucho mayor de lo que—según opinamos—se está anticipando.

PAGINA 4

PRONÓSTICO DE LA EXPANSIÓN FUTURA EN EL TRÁFICO TELEFÓNICO INTERCONTINENTAL

por M. Telford y G. A. Isted

Los ingenieros de comunicaciones coinciden en opinar generalmente no sólo que nuestro actual sistema de comunicaciones a larga distancia por radio ha alcanzado el punto de saturación, sino que—dada su dependencia en los fenómenos naturales—ya no puede ofrecer el servicio de alta calidad que exige el abonado de hoy en día. En sus mejores condiciones, el circuito radiotelefónico a larga distancia típico tiene una banda angosta, frente a las normas modernas. El mismo no puede transmitir mas de cuatro canales telefónicos de banda lateral única y, lo que es más, a menudo se encuentra fuera de servicio durante largos períodos de tiempo. Aunque el advenimiento del cable telefónico trans-oceánico ha cambiado las cosas en varias de las rutas principales, casi no se duda que hemos alcanzado el límite de lo factible en comunicaciones, siendo necesario un cambio revolucionario en las técnicas y facilidades si es que hemos de abastecer a las necesidades en lo futuro.

Antes de sugerir la forma que deberá tomar este cambio revolucionario, es preciso considerar qué nivel de expansión en las comunicaciones se puede prevenir en el futuro próximo. A tal fin se han adoptado tres métodos estadísticos. El primer método consiste en trazar un diagrama del tráfico a larga distancia que nos interesa, estudiando luego su desarrollo. Por ejemplo, la figura (Fig.1) muestra

las cantidades de llamadas telefónicas anuales por sistemas de radio a alta frecuencia, desde el Reino Unido hasta lugares fuera de Europa, a partir del año 1927. Los últimos datos incluyen llamadas transmitidas por el primer cable transatlántico (el TAT-1). Es muy interesante observar la regularidad de la curva que abarca los períodos en que el desarrollo natural no estuvo sujeto a influencias fuera del control de ingeniería, como asimismo la rapidez con que se vuelve a esta curva en cuanto desaparecen las restricciones externas. Pueden verse dos irregularidades principales: una de ellas evidentemente por causa de la guerra del 1939-45, y la segunda entre 1952 y 1957. Hubo un mínimo de actividad solar entre mediados del año 1951 y mediados de 1955, y casi no cabe duda que sus efectos perjudiciales a las radiocomunicaciones fueron una de las causas principales de la 'caída' de los años 1952-7, por la marcada insuficiencia, de cantidad y de calidad, de los servicios de radio, frente a las necesidades del tráfico. Después de instalarse el cable TAT-1, el número de las llamadas a tráves del Atlántico Norte desde el Reino Unido para el año cerrado al 31 de marzo de 1960 fué tres veces mayor que para el año terminado al 31 de marzo de 1956, aunque las llamadas radiotelefónicas originadas en estas islas habían crecido sólo en un 65% aproximadamente. Hay pocos indicios de una merma en el desarrollo del tráfico por el Atlántico Norte, y son comunes los períodos de espera de más de una hora durante la mayor intendsidad de tráfico, pese a que el número de circuitos disponibles en el cable ha sido aumentado a más del doble desde la fecha de su inauguración.

La regularidad con que crece el tráfico telefónico y la facilidad con que se explican las principales excepciones en este desarrollo permiten llegar a algunas conclusiones bastante sencillas. La Tabla 1 muestra los factores de desarrollo por década, en base a datos derivados de la Fig.1 y de las llamadas desde los EE. UU. en la Fig.2, de donde se verá que en los últimos 30 años las llamadas desde el Reino Unido y desde los EE. UU. de Norteamérica han aumentado en aproximadamente 66 y 117 veces, respectivamente.

Por el segundo método se establece una comparación entre el tráfico telefónico intercontinental y las facilidades derivadas de otros tipos de telefonía, como ser las llamadas internas en los sistemas nacionales. Los resultados están ilustrados en las Tablas 2 y 3. En la Tabla 3 se han dividido en tres categorías todas las naciones en que se dispone de estadística del tipo que interesa. Ellas son: (A) las naciones que cuentan con amplias facilidades telefónicas al exterior, (B) las naciones que tienen facilidades telefónicas al exterior regulares o malas y (C), aquellas naciones que cuentan principalmente con sistemas radiotelefónicos a alta frecuencia para sus comunicaciones telefónicas al exterior. Lo que más se destaca, probablemente, en estos datos es que las actuales facilidades para comunicación telefónica a larga distancia son—en la mayoría de los casos—completamente inadecuadas para hacer frente a las necesidades mundiales de hoy y del mañana.

El tercer método de estudio se basa en averiguar estadísticamente lo que ha sucedido con las demás formas de comunicaciones, y los resultados aparecen en forma gráfica en las Figs.3 á 7. En la primera de ellas se ilustra el número de pasajeros transportados por ferrocarril en el Reino Unido desde su establecimiento y hasta la fecha actual, mostrando además las millas de recorrido habilitadas. Se sugiere que el estado confuso de los datos a partir del año 1914 se debe a condiciones políticas y económicas inestables y por otra parte a la creciente importancia de otros métodos de transporte —sirve además como advertencia de los efectos que sufre un sistema de comunicaciones cuando no alcanza a abastecer las necesidades del momento, frente a una fuerte competencia. Al hacer comparaciones del desarrollo de medios de comunicación diferentes, es imprescindible seleccionar los períodos de desarrollo correspondientes. Esto se ha realizado en las Tablas 4 y 5, y parecería ser que el desarrollo de los dos medios de comunicación es muy similar.

La Fig.4 ilustra el crecimiento del tráfico de pasajeros por avión, a larga distancia, desde el Reino Unido y en casi igual período como el que aquí nos interesa. Es interesante observar que la forma de la curva es casi idéntica a la de la Fig.1, mientras la forma en que el tráfico volvió a recuperar su curva después de los atrasos por la guerra del 1939-45 y los desastres con los aviones Comet en el período del '55, hace pensar que el desarrollo está obedeciendo a una ley natural.

Antes de pasar a servirnos de los métodos descriptos anteriormente, para calcular el desarrollo del tráfico telefónico intercontinental en las próximas décadas, es menester examinar la situación actual. Esta aparece en la Tabla 7, que ilustra los cálculos de las actuales llamadas a larga distancia anuales transmitidas por cables trans-

oceánicos o sistemas de radio. Para mayor sencillez se ha hecho una división arbitraria del mundo en cinco 'zonas'. El total general es de alrededor de 5 millones de llamadas, y parece razonable suponer que el tiempo promedio de las llamadas facturables es de unos 7½ minutos. Así llegamos a una cifra global actual de alrededor de 12½ millones de unidades de llamadas de 3 minutos. Los factores de desarrollo para los próximos 20 años, calculados por los tres métodos, son los que aparecen en la Tabla 8. Si se toma un factor de desarrollo medio de 70 juntamente con el cálculo del tráfico telefónico global de la actualidad, cobrado a £1 por minuto, la renta anual de un sistema de comunicaciones eficientes en escala mundial en el año 1981 será de £2625000000.

La confianza en el porvenir, unida a la pericia de los ingenieros y proyectistas, serán menester para asegurar que las facilidades que aprontemos no sólo abastecerán la demanda de las dos décadas venideras sino que serán a la vez aptas para una expansión adecuada más adelante aún.

PAGINA 32

TRANSMISORES Y ANTENAS DE AF—EL PROBLEMA DE SU INTERCONEXION

por S. U. Nolan

En las estaciones transmisoras de alta frecuencia usadas en comunicaciones a larga distancia, la disposición de las antenas depende de la cantidad y la duración de los servicios en operación. La utilización de los transmisores no tiene restricciones similares y por ello los transmisores individuales deben conectarse a distintas antenas si es que se ha de lograr una utilización máxima. El problema de connectar transmisores y antenas se divide básicamente en tres partes, como lo demuestra la Fig.1.

Las antenas romboides son las que se usan más frecuentemente para comunicaciones a larga distancia y, puesto que las mismas son grandes, es preciso emplear largos tramos de alimentador para la conexión de las antenas con el edificio de la transmisora. Dado que las romboides requieren alimentador balanceado, y las líneas de transmisión a alambre descubierto son relativemente económicas, para esta finalidad se emplean siempre líneas de transmisión a alambre descubierto, aceptándose generalmente una impedancia de 600Ohms como término medio razonable de varios factores contrastantes.

Dentro del edificio de la transmisora, donde la densidad de las líneas de transmisión es elevada, no son convenientes los alimentadores balanceados a alambre descubierto, tanto por las dificultades físicas como por el peligro que representan las altas tensiones radiofrecuentes (ver Fig.3). El campo elevado de las radiaciones también presenta un problema difícil para las tareas de medición y mantenimiento. Sin embargo, los alimentadores balanceados han sido inevitables, ya que no se ha contado con un medio adecuado de conversión de desequilibrio a equilibrio a altas potencias.

La translación desde 50Ohms desequilibrados á 600Ohms equilibrados en el alimentador es factible, empero, mediante una disposición de las líneas de transmisión, disposición muy voluminosa, ó bien mediante transformadores con núcleo de ferrita. La disponibilidad de éstos últimos ha transformado la situación, en todo el alcance de la palabra. En la Fig.4 se ilustran ejemplos representativos: el más grande es capaz de transmitir una potencia de 20kW con una relación de amplitud de ondas estacionarias de 0,5, y ocupa un espacio de menos de 70cm en cada sentido. La disponibilidad de estos transformadores, que fué estimulada por el problema de conmutar antenas a 600Ohms, permite obtener una mejora fundamental en la situación actual, representada típicamente por la antena Miller que se ilustra en la Fig.6. Al contar con estos transformadores, la potencia RF dentro del edificio de la transmisora puede transmitirse por alimentadores coaxiles de baja impedancia, y de esta forma también es posible realizar la conmutación de antenas. Esto ha llevado al desarrollo de interruptores coaxiles sencillos, que pueden disponerse en una matriz (ver Figs.7, 8, 9 y 10). El tipo ilustrado en este caso particular consta con un dispositivo de reguridad, con el cual se obtiene una interconexión positiva entre antenas y transmisores. La transformación de desequilibrio a equilibrio tiene lugar del lado del interruptor más próximo a la antena, usándose alambre descubierto para la conexión a las antenas, tal como al presente.

La disponibilidad de un medio adecuado de transformar la energia radiofrecuente ha permitido el desarrollo de interruptores de antena coaxiles: las dos técnicas, a su vez, permiten efectuar una simplificación fundamental en el método de encarar este problema.

PAGINA 46

UNA MANERA DE MEJORAR LA ESTABILIDAD DE FRECUENCIAS

Pese a que los osciladores a cristal comunes son adecuados para evitar la interferencia entre transmisiones en frecuencias adyacentes, algunos de los métodos modernos de la modulación, proyectados con el fin de lograr comunicaciones más efectivas, precisan una estabilidad del oscilador de 5 partes en 10^7 ó mejor aún. Tales sistemas incluyen la operación en telefonía con banda lateral independiente a portadora suprimida y con portadoras sincronizadas, y con manipulación por desviación de frecuencia en la telegrafía.

Para tales finalidades deben seleccionarse cristales con buenas características de envejecimiento, a los que se debe controlar térmicamente dentro de menos de 0,1°C. Los ambientes térmicos de gran estabilidad para los cristales son generalmente controlados mediante un puente térmico, seguido por un amplificador sensible a las variaciones de fase y por un relé. Estas complicaciones se pueden evitar empleando un nuevo tipo de horno, que se sirve del punto de fusión de una sustancia cristalina para la estabilización de la temperatura. La propiedad del calor latente en la fusión da una regulación térmica efectiva para las variaciones cíclicas de temperatura debidas a la conmutación de hornos, a la vez que la propiedad de cambio de volúmen durante la fusión sirve para controlar la entrada térmica al horno.

La Fig.1 ilustra una sección de este tipo de horno auto-adaptable. El cristal se halla montado en un anillo protector sobre un soporte aislado térmicamente, que se introduce en una cámara interna desde uno de sus extremos. En el extremo opuesto hay un fuelle metálico flexible dispuesto de manera que opere a un micro-interruptor para controlar la potencia de calefacción del horno. El interior del horno está cargado con naftalina, con punto de fusión de 79,5°C y que se expande volumétricamente en 12% al fundirse. El calor, proveniente de un calefactor al externo del horno, causa la fusión de una capa del relleno alrededor de la cámara del cristal, dejando libre al fuelle, que desconecta la potencia calefactora no bien haya fundido una cantidad predeterminada del relleno.

Rendimiento

Potencia del horno: 30 W

Ciclo de conmutación: Encendido, 20 segundos; Apagado, 80 segs

Tiempo de caldeo: Dentro de 1 en 10^7 partes, en 35 minutos

Error cíclico: $\pm$ 0,0014°C ó $\pm$ 7 en 10^{10} partes, para cristales con coeficiente térmico de 5 en 10^7 partes por °C

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- ✳ **Fully transistorised, mains or station battery operation.**
- ✳ **Optional inbuilt out-band 3825c/s signalling, ring down or dialling.**
- ✳ **New racksides of high equipment capacity within conventional rack dimensions.**
- ✳ **Readily installed and extended with minimum station cabling.**
- ✳ **Compact, reliable, versatile.**

Write for further information to:—

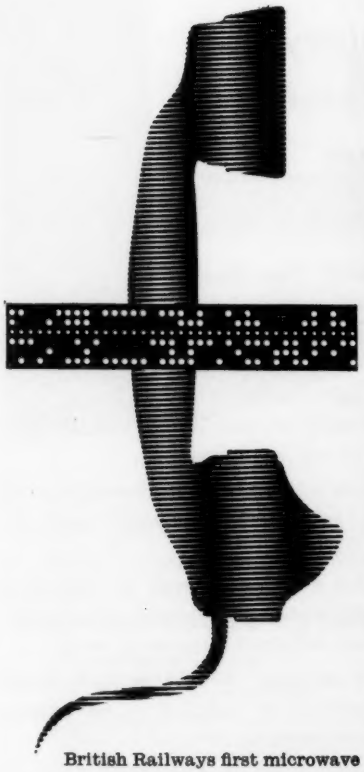
AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

Strowger House, Arundel St., London, W.C.2.

'Phone: Temple Bar 9262

ATE

AT8961



FIRST RAILWAY MICROWAVE RADIO TELEPHONE SYSTEM IN BRITAIN

300 Channels between Newcastle and York

British Railways first microwave multichannel system from Newcastle to York via Darlington will have a 300 telephone channel capacity. The system allows for channels to be dropped off at intermediate points and can accommodate high speed data transmission.

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COMPLETE COMMUNICATION SYSTEMS
SURVEYED · PLANNED · INSTALLED · MAINTAINED

COMMUNICATIONS DIVISION
MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND
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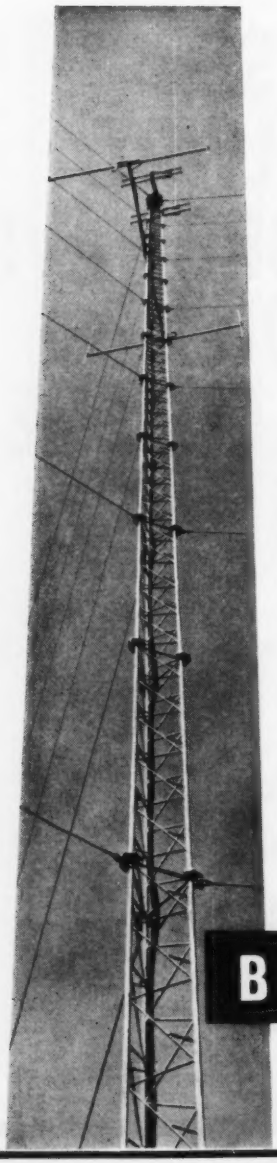

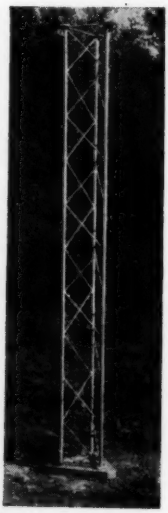

For simplicity and speed in mast erection

The BICC Unit Radio Mast is made up from identical 10 foot sections. Designed to meet the demand for an inexpensive, light, transportable aerial supporting structure, it is already in use in 25 countries.

Sections are supplied from stock complete with stay ropes, anchors and accessories ready for immediate erection.

These Unit Masts can be built to a maximum height of 150 feet at which they will carry a 1,000 lb. head load and withstand a 100 m.p.h. wind.

An added advantage: BICC Unit Radio Masts are easily erected by unskilled labour with a minimum of supervision.

Other types of unit construction masts are available up to 300 feet high.

BICC GALVANISED STEEL **UNIT RADIO MAST**

The BIC Construction Company undertakes the design, supply and erection of a wide range of radio masts and self-supporting towers to customers' requirements.

British Insulated Callender's Construction Company Ltd. 30 Leicester Square, London, W.C.2

1010

A **MARCONIDATA**

DATA COMMUNICATION SYSTEM
DOESN'T EXIST

UNTIL WE BUILD IT FOR YOU

MARCONIDATA is backed by a name made famous in every country of the world for telecommunications practice and technique.

MARCONIDATA the product of the largest research and development organization of its type in Europe, is a completely flexible system composed of standard sub-units which can be arranged to provide accurate data communication between any number of points over any distance.

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COMPLETE COMMUNICATIONS SYSTEMS

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FAST ACCURATE DATA COMMUNICATION SYSTEMS

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND

H4D

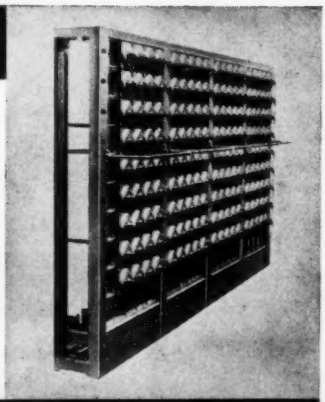
AERIAL SWITCHES

COAXIAL FEEDER SWITCH TYPE HA 150

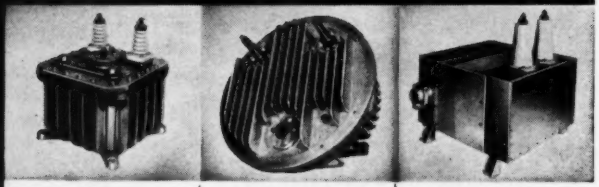
A number of switch units are linked together in a matrix type of construction to form a feeder exchange. Transmitters can be selected to feed the requisite aerials with complete flexibility. Interlocking facilities for transmitter protection are incorporated. Personnel safety is ensured.

POWER HANDLING CAPACITY: 20 kW continuous rating 30 kW p.e.p. (with 2:1 SWR)

FREQUENCY RANGE: Up to 30 Mc/s Nominal Impedance: 50 ohms



HIGH POWER MATCHING TRANSFORMERS



	HA 111	HA 112	HA 113
FREQUENCY RANGE	2-27.5 Mc/s	5 kW editions: 2-27.5 Mc/s 7 kW editions: 4-27.5 Mc/s	4-27.5 Mc/s
POWER RATING (for matched termination): Ambient temperature 40°C 45°C	*2Mc/s 10Mc/s 20Mc/s 27.5Mc/s* 2kW 1.15kW 0.8kW 0.6kW 1.65kW 0.99kW 0.7kW 0.52kW	5-7 kW according to edition	20 kW with 2 : 1 output SWR
TRANSFORMATION RATIO	75/600Ω or 50/600Ω unbalanced to balanced	50/600Ω or 75/600Ω unbalanced to balanced	50/450Ω unbalanced to balanced (matching to 600Ω via tapered open line)
INSERTION LOSS	Negligible — in all cases		
STANDING WAVE RATIO	Not greater than 1.3 for a matched termination in all cases		
LIMITS OF AMBIENT TEMPERATURE	—40°C to +50°C in all cases		
LIMITS OF HUMIDITY	95% in all cases		

MARCONI

COMPLETE COMMUNICATIONS SYSTEMS

SURVEYED · PLANNED
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COMMUNICATIONS DIVISION, MARCONI'S WIRELESS TELEGRAPH COMPANY LTD., CHELMSFORD, ESSEX, ENGLAND

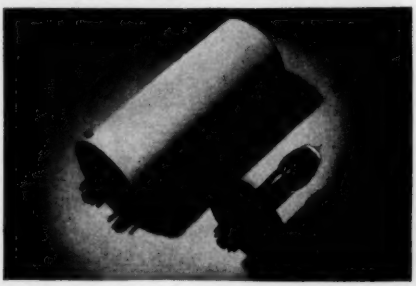
H6

Quartz Crystal Ovens

STABLE TEMPERATURE ENSURING MAXIMUM FREQUENCY STABILITY

Switching differential 0·0014°C.
No thermostat
No thermometer switch

Orthodox crystal ovens, using thermostats or thermometer switches, are available for applications where wider temperature variations are acceptable.



This symbol has been adopted by the Marconi Specialized Components Group. The Marconi Company undertakes the design and manufacture of specialized components only when no suitable alternative is available; and in almost every case, Marconi specialized components are designed to more exacting standards and built to closer tolerances than any similar components. A preliminary catalogue is available, listing ferrite isolators and circulators, coaxial connectors, attenuators, terminations and switches; waveguide filters terminations, and bends; crystal filters and ovens.

MARCONI

SPECIALIZED RADIO COMPONENTS

Write for details of crystal ovens and other specialized components in the Marconi range, and address your enquiries to:

SPECIALIZED COMPONENTS GROUP

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD.
CHELMSFORD, ESSEX, ENGLAND

W2

THE BEST DUAL-TRACE BUY

15 Mc/s OSCILLOSCOPE £390

- D.C. to 15 Mc/s, twin Y-inputs, with 50 mV/cm sensitivity
- 0·02 μsec/cm to 1 sec/cm writing speed
- Rise time 25 mμsec; scale discrimination, 10 mμsec/cm
- Choice of alternating or chopped display
- Built-in differential amplifier
- 2% measuring accuracy on voltage and time
- Less than 2 mμsec delay between channels
- Can also be switched to single-beam operation

MARCONI INSTRUMENTS

The price of the TF1331 is well below that of any dual-trace oscilloscope of comparable specification. A quality general-purpose instrument, it incorporates the high accuracy voltage and time measuring methods standard with Marconi oscilloscopes.

Two switch-selected D.C. coupled inputs are provided, each with its own coupling, sensitivity and shift controls, together with a polarity reversing switch. The channels can be displayed either on alternate sweeps or at a switching rate of 250 kc/s.

The built-in differential amplifier is particularly useful for standardising or comparing waveforms, and for measuring phase delay between pulse trains in pulse code modulation systems and radar.

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REPRESENTATION IN 68 COUNTRIES

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